Neighbourhood level determinants on mode choice and distance for home-based work trips in the Montréal region:

A factor and cluster analysis of demographic, urban form and accessibility measures to better understand regional travel behaviour

Supervised Research Paper

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ABSTRACT

In the past several decades increases in personal mobility brought on by technological advances and other land use and transportation factors has led to lengthening the daily commutes for many North Americans. Most of the increase in daily mobility is by privately owned vehicles. This increase in vehicle miles travelled (VMT) has lead to drastic increases in pollution and congestion. In an era of rising fuel costs, an unsure energy future, and climate change, understanding the factors leading to longer car trips is indispensable for planners and policy makers aiming towards lowering total vehicle miles travelled. The goal of this research is to better understand home-to-work travel behaviour throughout the Montréal Metropolitan region. This is undertaken in several steps. First, a factor and cluster analysis of demographic, urban form, land use and accessibility measures is performed over the entire region based on a fine-scale grid pattern. This information on neighbourhood characteristics is then combined with detailed personal and household data available from the 2003 Montréal Origin-Destination Survey on over 40,000 home-to-work trips. In addition, a linear regression is developed to explain trip length as a function of personal, household and land use characteristics at the point of origin and destination for automobile trips. Finally, a sensitivity analysis is used to understand the effects of neighbourhood types on trip length while controlling for the geographic location. It is shown that suburb-to-suburb commuting is both more prevalent and not as long as expected. Commuters who cross bridges to downtown are travelling much further than those who live and work in the same sub-region. The approach developed here is shown to be useful in understanding regional travel behaviour and points towards further study and discussion in this vital area of transportation research.

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INTRODUCTION

The influence of transportation technology, infrastructure, policy, government funding, and increasing personal wealth over the past century has had a profound influence on daily travel patterns. Daily commuting distances for many North Americans today are much larger than commuting distances from a decade or two ago. While, much of this mobility has an undoubtedly positive influence on quality of life in the form of access to emergency transportation, cultural opportunities, tourism and the ability to match residential preferences with job location preferences, there exists a vast array of negative externalities in the form of pollution, sprawl, congestion and social equity.

Crane and Schweitzer (2001) summarize the resource problems associated with widespread of automobile use. Apart from the obvious adverse effects of fuel combustion, they also include other factors such as noise, health issues related to physical inactivity, difficulty in recycling car parts, waste oil, social and economic disruption, visual blight, safety issues, and the feedback loop between auto use, road construction and sprawl. Many of these problems could be addressed through lowering VMT on North American roads. They also note that while technological advances in the form of “cleaner” cars may reduce emissions from fossil fuel combustion, they will little to stem the proliferation of low-density, auto-dependent places, improve road safety, get people walking for exercise, or slow the demand for new road construction.

Put another way, the simple substitution of conventional combustion engines with hybrid or bio-fuel vehicles without changing current North American driving habits is clearly not a long-term solution. While the adoption of alternative fuels and more efficient engines is clearly welcome, particularly for transport and transit purposes, it will never solve the wider issues of congestion, wasted time and capital. It is with this in mind that it is suggested that the distance traveled is the most pressing issue. Reducing Vehicle Miles Travel (VMT) could be considered the most efficient way of reducing pollution and congestion.

Studies have shown that personal automobiles are producing a growing proportion of pollution and green house gas emissions. For example, Marquez and Smith (1999) showed that 18% of British Greenhouse Gas Emissions (GHG) emissions are from personal car usage. According to the U.S. National Household Travel Survey (Hu and Reuscher 2004) home-to-work travel contributes to 27% of total VMT in American cities. For that reason, reducing VMT related to home-to-work travel can be a key element leading towards sustainable travel patterns.

Although daily home-to-work trips make up only a portion of the total vehicle miles travelled, there are several sound reasons why this is the basis of this research. First, shopping and social trips are much less likely to be regular and consistent. Also, as Shearmur (2006) points out, the home-to-work commute often serves to structure other trips made during the day. In other words, where one shops is more likely to be influenced by one’s work location than the opposite. In addition, home-to-work trips are likely to be repeated every day, therefore a thorough understanding of work trips is absolutely vital in attempting to characterize regional travel behaviour.

In the past several decades, there has been a proliferation of research concerning the relationship between built form and travel behaviour. The importance of this research is obvious, with vital implications for planners, policy makers and environmentalists.

Much of the current debate in the ever-elusive realm of land-use-travel behaviour connection is couched in claims made by new urbanists, and smart growth and other “anti-sprawl” advocates about the connection between built form factors and travel behaviour. Much of the design underpinnings of many new urbanist communities, in fact, are based on the assumption that design and travel behaviour are intrinsically linked. While the idea is attractive, after all, why wouldn’t more pedestrian friendly design and locating origins and destinations closer together cause more people to make shorter, non-motorized trips? While it may seem self-evident that more dense neighbourhoods with social and economic activities located in close proximity to one another will lead to less resource depleting car trips, many other factors are at play when individuals and households make location and travel decisions. As will be demonstrated below, one of the liveliest debates in modern transportation planning deals with just this issue. At the heart of most discussions in planning circles regarding these issues is the idea of how urban form, demographic factors and location affect travel behaviour.

In short, changing travel behaviour through urban design remains a vision rather than a reality for planners, designers and policy makers. It appears that changing people’s attitudes is the major obstacle in making long-lasting behavioural changes in much of the population. Reaching this point is not possible without a clear understanding of the factors affecting VMT and mode choices.

Montréal is currently adopting a comprehensive transportation plan that aims at reducing the dependence on single occupancy vehicles and encourages alternative modes (Ville de Montréal 2008). Knowing the factors affecting trip distances will help in recommending a set of policies that would have the highest impact on Montréal residents. The lessons learned from this study can be beneficial to other regions in North America and around the world that are facing similar challenges and trying to promote shorter distances as a way towards more sustainable land use policies and transportation systems.

LITERATURE REVIEW

This brief literature review will attempt to introduce some of the key concepts, debates and findings in the discussion of the complex relationship between urban form, personal preferences, demographics, residential choice and travel behaviour.

The amount of published material on the links between land-use, accessibility, and socio-economic variables over the past three decades is staggering. Ewing and Cervero (2001) and Badoe and Miller (2000) are both excellent introductions to many of these issues. They present methodology and findings of over 50 published papers on these issues and are valuable resources for previous studies. While the degree to which travel and built form variables are connected is hotly debated, most studies have found there is a correlation between certain key variables and travel behaviour.

EVOLUTION OF URBAN FORM AND THE RISE OF THE AUTOMOBILE

It is beyond the scope of this paper to examine the evolution of the automobile-centric nature of most North American cities. For detailed discussion about the evolution of North American road design and the demise of the once-flourishing public transit system, recommended texts include, among others, Dupuy (1999) and St. Clair (1981). St.Clair, in particular, offers an interesting treatise on the controversy surrounding the failure of many streetcar systems in American cities in the early 20th Century and the subsequent rise of the automobile over the decades.

In brief, for centuries, technological advances have gradually allowed for the increasing distance between workplace and home. As horse drawn carriages and later streetcars became the dominant form of transport, the distance between home and work started to increase dramatically. As public transit evolved and grew in North American cities in the late 1800's and early 20th Century, these home-to-work distances continued to expand.

The widespread use of automobiles in the second half of the 20th Century has led to unprecedented levels of personal mobility. With the growth of auto use, the very form of the city was changed to accommodate cars. Safdie and Kohn (1997) describe the "misfit" between the scale of North American cities and their transportation systems. While streetcar suburbs grew up along transit routes and remained relatively compact, the car, along with decreasing fuel costs, more efficient engines, not to mention government subsidized highway construction converged to create a situation where personal car ownership became not just practical, but essential for many urban dwellers. At the beginning of the 21st Century, we live in a car-dominated world where the vast majority of trips in North America are taken in what is arguably the least energy efficient and most polluting option available.

NEW URBANISM AND "SMART GROWTH"

Many popular design philosophies have arisen in the last few decades with an expressed purpose to question and improve upon the conventional suburban built form of much of North America, chief among them new urbanism, neo-traditional town planning, transit-oriented development and Smart Growth. It is beyond the scope of this paper to fully address all of the complex issues of these movements. See especially Katz (1994) and Duany, Plater-Zyberk et al (2000) for a detailed description of the goals and aims of new urbanism. At the crux of these design philosophies is the assumption that design can influence travel behaviour. While new urbanism also addresses issues of social interaction, community, and architectural design, the concern in this paper is solely on the issue of travel behaviour. While new urbanist communities have grown in popularity over the past two decades and studies have shown some success in the reduction of auto trips, there remains much controversy regarding the extent to which the particular design features of new urbanism are working towards reducing car usage.

Another important aspect of new urbanism is the spatial distribution of these developments. A neighbourhood that encourages walking and cycling might be successful for internal social and leisure trips, nevertheless, the availability of employment, entertainment and other commercial activities nearby will influence the number and length of car trips much more than anything related to neighbourhood scale design. Many of these factors are market driven. Accordingly, it might take several years for commercial activities to sprout up around a new residential development. Conversely, it could be argued that travel behaviour in infill developments is less dependent on internal factors than the fact that, by definition, shops and employment opportunities are most likely nearby. Many new urbanist neighbourhoods are designed to facilitate internal walking and cycling trips but located such that exiting neighbourhood generally requires a car.

Previous Studies

In an important contribution to this research, Cervero and Kockelman (1997) outline many of the research methodologies and describe the "3Ds" of: density, diversity, and design. It is through these key elements, it is thought, that policy can influence travel behaviour.

The most elusive aspect of this debate concerns causality. In other words, it is straight-forward enough to show that residents of far-flung single-use residential areas with limited local services travel further than residents of dense, mixed-use centrally-located areas. However, a very basic examination might reveal that the former is full of wealthy, car-owners with a stated preference for driving and living on large lots, while the later neighbourhood is a low-income area with little car ownership or residents with a stated preference for walking. In other words, without controlling for these demographic variables, the findings could very well be meaningless. Most importantly, it would clearly be misleading at best to claim that neighbourhood characteristics *caused* the resultant travel behaviour.

If researchers are not careful to control for these issues, there might be strong autocorrelation. For example, researchers have cautioned on the over-simplification in correlating density with both mode choice and distance. Often, dense areas have a much lower median income (Crane 1996; Boarnet and Crane 2001). As well, dense urban areas are often well served by transit, have limited parking and have employment and commercial opportunities located in close proximity. Therefore simply increasing suburban residential density would have little to no effect if an effort is not made to increase transit infrastructure, mix commercial and residential land uses and limit parking. Other researchers have remarked that the share of rental dwellings and residential density both act as proxies for income. They suggest that, as many older parts of cities offer a predominantly rental market, the easy assertion that older development, pre-1945, offers better walkability is not so clear. Perhaps it is simply that more people who cannot afford a car live there (van de Coevering and Schwanen 2006).

This is the difficulty, turning this correlation into a causal relationship. The primary concern is one of self-selection whereby households who enjoy walking or cycling choose to live in areas where this is possible. This is arguably the core of the issue. In other words, do neighbourhood characteristics influence behaviour or does behaviour influence choice of neighbourhood?

In order to prove a causal relationship between two variables, four criteria must be met: statistical association, cause precedes effect, non-spuriousness, and a known mechanism (Handy, Cao et al. 2005). This statistical association has proven to be difficult to obtain. However, research that employs surveys of preference, and questions about past residential choices, as well as longitudinal studies can approximate this type of inquiry. In short, in-depth understandings of these issues can only come from an in-depth analysis of urban form and demographic facts, as well as a thorough understanding of a household's preferences, tastes, past behaviour and future plans.

Handy (2005), in a quasi-longitudinal study, did find evidence for a causal relationship between changes in travel behaviour and the built environment. However, a previous study by Handy and Clifton (2001) found that self-selection largely explained the observed differences in travel behaviour. Some studies have looked at personality types and travel behaviour noting that extroverts make more non-work trips than introverts and that certain character traits of urbanites might vary from suburbanites leading to those residential choice decisions (Prevedouros 1992).

Some studies (Kitamura, Mokhtarian et al. 1997; Limtanakool, Dijst et al. 2006) develop an extensive questionnaire to capture household preferences. These types of studies can reveal much about attitudes and go a long way towards understanding the relationship between urban form and travel. Kitamura *et al*. (1997 p. 156), in fact conclude that "Attitudes are certainly more strongly, and perhaps more directly associated with travel than are land use characteristics" They propose that land use policies alone will have minimal affect on travel behaviour without a corresponding change in residents' attitudes.

The issue is more about making these neighbourhood types more desirable for more people who could otherwise "afford" to own a car and live in the suburbs. As Badoe and Miller (2000) point out, this last point brings up another question, namely, are these types of dense mixed-use neighbourhoods under-represented in the marketplace?

Another key issue concerns "trip replacement". Studies often point to the fact that residents might walk more in certain neighbourhoods. While this is clearly a positive step for health and social reasons, if the same person still commutes twenty-five kilometres a day at peak hours, it is arguable whether there is much improvement in overall congestion and pollution. Interestingly, Crane (2000) presents a chart showing how design elements such as grid-based street patterns, mixed land uses, traffic calming devices, as well as combinations of all three have been seen to both increase car trips, VMT and car modal split, this is a clear indication that these issues are still very much open for discussion. Cameron, Kenworthy *et al*. (2003) however found that urban form factors on their own explain 85% to 92% of the variance in private automobile use and that therefore; urban form can lead to a close approximation of a given region's emissions.

The findings concerning mono-centric versus polycentric urban form are often contradictory, on the one the hand, while a polycentric form might allow residences and places of work to be closer together, the ownership and use of automobiles has also grown as North American cities that have this type of spatial pattern. This is the conclusion of Schwanen et al (2001) in a study of Dutch cities. They found that the "de-concentration" urban land use "almost certainly promotes," car usage, particularly in cross-commuting, that is, commuting from one suburb to another. Research of Coevering and Schwanen

(2006) also found that a higher percentage of jobs in the CBD was correlated with shorter daily commutes.

Demographics

The other primary factor in travel behaviour is demographics. While not all research is conclusive, and much disagreement exists on the magnitude and importance of certain factors, there have arisen several accepted general thoughts on how income and household characteristics impact travel behaviour.

Correlations between car ownership and income have been widely documented. Cameron et al. (2004) however, present a case that policy makers and planners have tools at their disposal to control this "inevitable" feedback loop. The last several decades have been both an era of unprecedented urban growth with an accompanying increase in personal and household wealth. He cites several Asian cities that have successfully avoided becoming car-dependent despite increasing wealth and car ownership.

One line of reasoning concerning the increased use of the private automobile as income increases is related to the value of time; the argument goes that as income rises so does the value placed on time. The fact – or at least the perception – that cars are a much faster means of transportation would of course lead to more ownership and use. In fact, Lave (1985) lays the burden of declining transit use squarely on the shoulders of increased economic strength.

However, others have speculated a differing view on the value of time. If time spent in a daily commute is conceptualized as a cost, higher paid workers would be more willing and able to "pay" the cost of longer commutes. In fact, from an economist's viewpoint travel decisions are thought of as simply a trade off between salary, travel costs and housing costs (Shearmur 2006). While this is somewhat simple to understand in a mono-centric city, the poly-centric nature of most North American cities makes this much more complex to model. However, it is becoming more common to model these relationships interactions (Schwanen, Dieleman et al. 2001; Dieleman, Dijst et al. 2002).

Downs (1994) breaks the issue down to the inherent contradiction between the residential, transportation and workplace desires of North Americans. He writes that the most common "vision" for most North American households is based on four pillars. One: owning a detached, single family home on a large lot. Two: a privately-owned vehicle *and* uncongested roads. Three, low rise, "park-like" suburban workplaces, and four, strong local governments that will strictly control land use and allow for citizen interaction with policy. This last point, in Downs' theory, serves to keep the character of the suburban landscape by limiting unwanted land uses, in particular social housing and more dense development. The contradiction as Downs states it is obvious, if most North Americans live on large lots and drive single-occupancy vehicles at peak hours every day, uncongested roads are impossible to maintain. While few would seriously question whether larger lots and spatially segregated land uses causes *longer* commutes, achieving consensus on the policy implications this has proven to be quite difficult.

Builing and Kanaroglou (2006) conclude that many land use policy attempts to facilitate more transit use and shorter trips are often thwarted by the "tastes and preferences of households". They also found, in agreement with Giuliano and Small (1993), that rising mobility in the last several decades "reduces the significance of the regional distribution of employment as a determinant of travel behaviour". They also question the degree to which minimizing commuting time plays in residential choice decisions. In short, this line of research has shown that demographic factors are more likely to influence travel decisions and behaviour than land-use policy changes. In other words, even though better transportation technology and more lanes of traffic would arguably allow people to reduce their time cost in daily commuting, many seem to prefer to simply live further from work instead of taking advantage of this "time saving" option.

Gender has also been shown to be a major determinant in travel behaviour, with males, travelling farther in daily commutes. Income and education have been shown to be significant factors in contributing to longer commutes. It has been hypothesized that lower income jobs have a better spatial distribution than many high income jobs that will be located in concentrated in particularly areas. For example, hospitals, universities, office towers, suburban office parks in contrast to retail and service, convenience stores and so on that will be somewhat evenly dispersed throughout an urban region. In other words, one might always be near a low-income job, but kilometres away from a high-paying skilled employment. Guiliano and Small (1993) present evidence from Los Angeles that suggests that administrative and technical workers commute up to 40% longer than service workers. Other research suggests that certain sectors of employment, trade and transport for example, tend to be located in low-density areas along highways thereby making the modal split by car much higher for workers employed in these fields (van de Coevering and Schwanen 2006).

Urban Form Classification and Analysis

The importance of understanding various urban forms has long been understood as central to informing policy in land use and transportation. In recent years it has become even more vital to accurately and objectively describe land use and urban form as words like "sprawl", "suburban" and even "mixed use" become loaded with meaning and, at times, misuse. Recent research has highlighted the importance of distinguishing between various types of sprawl (Talen 2002). Others have criticized the over-simplification of defining suburbs simply as their distance from a downtown core (Song and Knaap 2004). Terms like mixed-use can have several meanings. Several studies have looked at he differences between various employment centers in the Montréal region (Coffey and Shearmur 2001; Shearmur and Coffey 2002). Previous Factor and Cluster analysis in other North American cities (Cervero and Kockelman 1997; Song and Knaap 2004; Wilson, Krizek et al. 2004) have identified several recurring types of development. Several additional studies have focused on identifying employment sub-centers (Anas, Arnott et al. 1998; McMillen 2004).

Talen (2002) in an excellent introduction to many of the inherent issues at play when discussing, defining and analyzing urban form, writes of the dangers of selecting variables that are "rarely neutral[…] and can be loaded with subjective meaning". She highlights the pitfalls of attempting to measure and define "sprawl" and emphasizes the need to separate what could be called "good" or "bad" sprawl. In other words, she asks, "is *all* development at the outer edges of an urban region sprawl?"

Simplified diagram

It might be helpful to visualize how previous researchers have presented the complex interactions of demographic, land use and policy interactions on travel behaviour. The first, Figure 1, is a – purposely – simplified version while Figure 2 attempts a more thorough accounting of the factors.

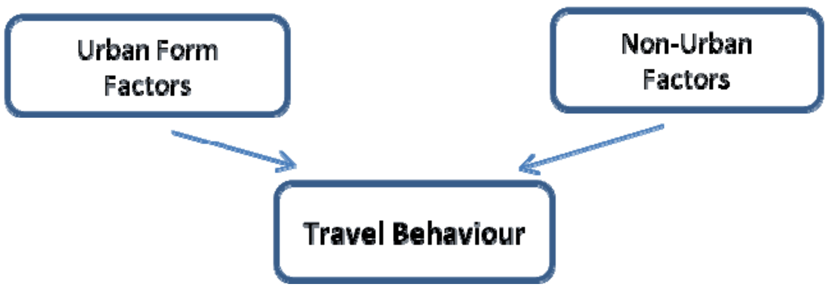

Figure 1: Simplified diagram of urban form and non-urban factors influence on travel behaviour
Adapted from Frank and Pivo (1994).

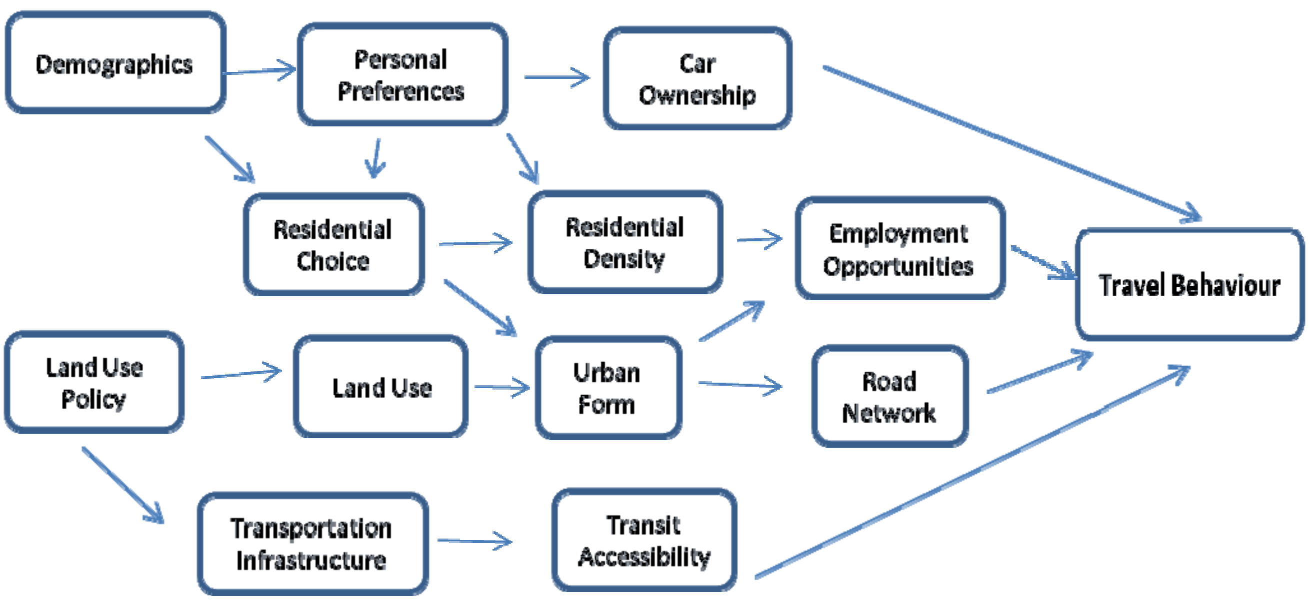

Figure 2: Demographic, land use and policy interaction in determining travel behaviour
Adapted from Badoe and Miller (2000) and Knaap and Song (2004)

Here it becomes clear how personal preferences and economic factors, along with public funding, infrastructure availability, and land use characteristics interact in intricate ways to influence the travel behaviour of a given individual or household. Bear in mind that this is itself somewhat simplified, several factors would be included in the demographics category, for example family size, income; a household's residential choice might change over time as incomes and household size increases. Also, as Badoe and Miller (2000) point out, the complex "feedback" interactions are difficult to show in this diagram. For example, travel behaviour decisions affect overall road congestion which might alter another user's behaviour and choices. From a supply and demand viewpoint, neighbourhood travel decisions might, over time, affect the level and frequency of transit service – in either direction. These complex interactions are vital in understanding these issues.

STUDY CONTEXT

Montréal is among the largest cities in North America. While Montréal has a lively and economically active urban core, recent years have seen suburban sprawl extend further into the surrounding regions. Montréal's location on an island in the St. Lawrence River connected to the mainland by 14 bridges and a tunnel makes issues of traffic congestion from outlying suburbs even more pressing. Considering that a large amount of daily traffic is concentrated in these corridors, understanding trips that cross one of the bridges has important implications for planners.

Montréal has an extensive public transit system comprising bus, metro and commuter rail lines extending far into the region (see Figure 3). Public transit also sees a large percentage of trips in the region. While Montréal has a strong downtown employment center, prior research has identified six employment sub-centers. Four are located on the island of Montréal: the CBD, Anjou, Chabanal and Dorval, in addition, "downtown" Longueuil, and Laval on the South and North Shore respectively. While Montréal is clearly not a mono-centric city, it should be noted that the largest concentration of jobs is on the island and in the CBD in particular. It is estimated that 182,000 jobs are located in the CBD alone (Coffey and Shearmur 2001). In addition, although the city still has a vibrant core, the growth at the centre has slowed recently in relation to outlying areas (Collin, Dagenais et al. 2003).

The region of Montréal extends north towards the Laurentians as well as west and South towards the Ontario and U.S. border. The Montréal Metropolitan region contains dozens of municipalities, many of which were historically rural, farming villages. While it could be argued that the city has sprawled over the last several decades, most development has remained along linear paths defined by major expressways, most notably the 15, 30 and 20.

The Island of Montréal includes the City of Montréal, made up of 19 boroughs, as well as 15 other "reconstituted" cities that "demerged" in 2006 after the 2001 merger. The region includes 82 municipalities, each run by their own local government.

According to statistics from the Communauté métropolitaine de Montréal, the region covers an area of 4,360 square kilometres and had a population of 3.6 million in 2007 with 1.4 million private dwellings, 1.84 million automobiles and 1.86 million jobs (Communauté Metropolitan de Montréal 2009).

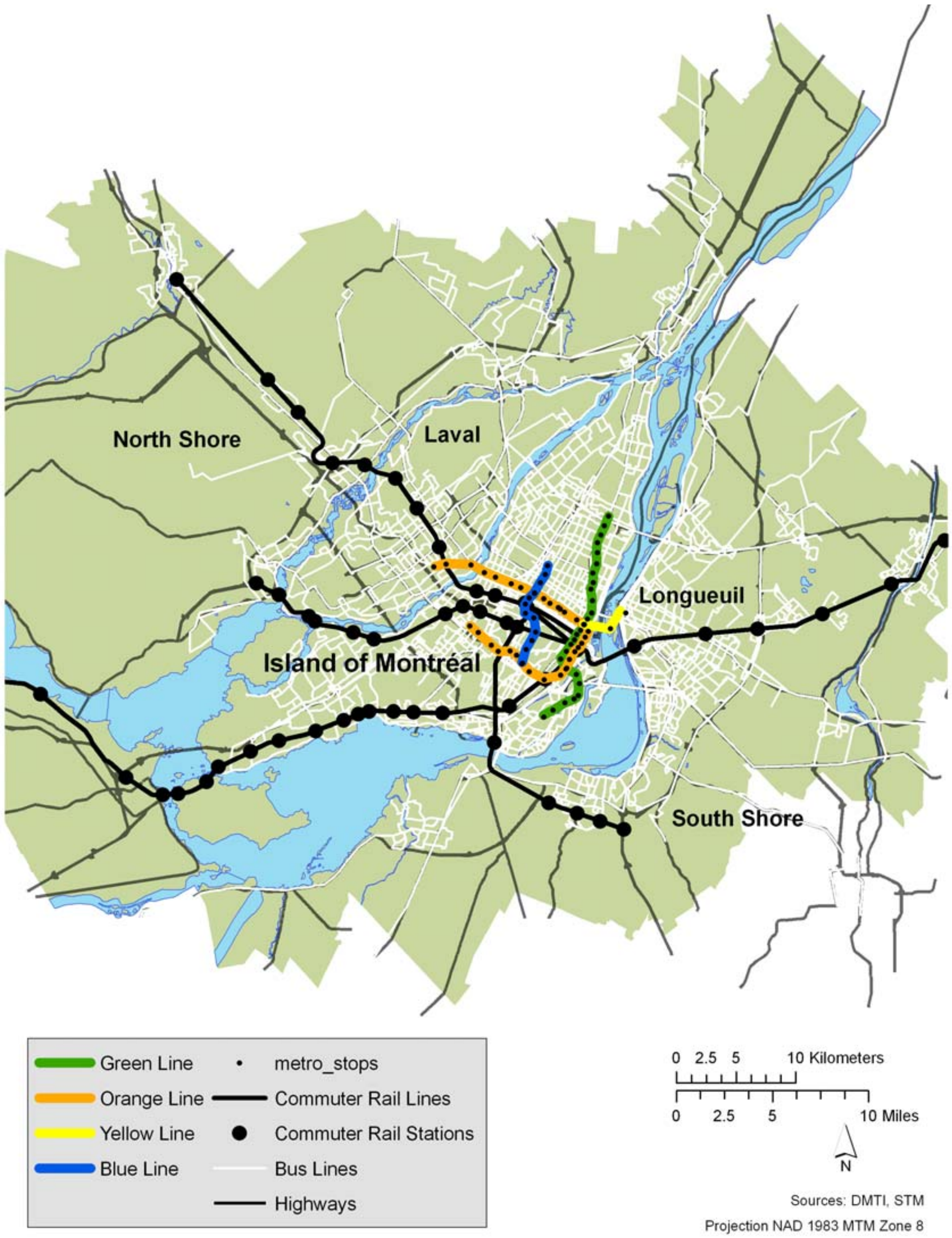

Figure 3: Regional Transit Map of Montréal

METHODOLOGY

The travel behaviour literature suggests three main factors affecting trip length and mode choice. These factors are 1) spatial configuration of land use and transportation at origin and destination; 2) socioeconomic characteristics of traveler; and 3) travel costs associated with different modes (Cervero and Kockelman 1997; Limtanakool, Dijst et al. 2006). Since the goal of this research is to better understand the link between trip length and personal, household, neighbourhood, and destination area characteristics, variables at each level are needed.

For the neighbourhood level I identified thirty-six different variables that can have an effect on trip length. These variables include land use, urban from, demographics, accessibility to transit and degree and type of commercial activity. Then a data reduction technique was used to consolidate these local neighbourhood characteristics into a small set of variables. To do so, the Metropolitan region was divided into 150m x 150m grid cells. The selection of the grid cell size was based on reviewing previous research modeling land use changes over time. For example UrbanSim uses a 150 metre grid cell (Waddell 2004). Factor and cluster analysis techniques were utilized to classify each grid cell to be part of a certain neighbourhood type. This classification took into account the neighbourhood characteristics in the cell as well as the cells adjacent to it. This means that there are two scales to the design, a central cell of 150m x 150m and a combined cell of 450m x 450m.

Travel distance from home to work was obtained from the 2003 Montréal regional Origin-Destination survey (OD survey) using GIS software. The O-D survey is a metropolitan survey that is conducted every five years in the Montréal region (AMT 2003). The O-D survey includes disaggregate data on all trips that were made by each person in a participating household. The survey includes 5% of all households in the Montréal Region. Data from the OD survey will be also used for the personal and household characteristics. Trip characteristics, length, mode, purpose and time of departure will also be obtained from the same dataset. Variables at the individual level include gender, age income, and total number of trips. At the household level variables include number of people per house, number of vehicles, and total number of trips.

While many studies have made use of factor and cluster analysis to identify neighbourhood types or regional sub-centers, it is less common to use separate factor and cluster analyses of both home and work locations.

This paper will make use of several multivariate techniques in first reducing a substantial amount of data on several thousand individual grid cells with over one hundred variables using *factor analysis*. Then, the technique of *Cluster analysis* will further reduce the data by sorting the cells into much smaller groups. Later *binominal logistic models* and *multivariate regression* techniques will be used to test the dependence among variables by attempting to predict the likelihood of using a car for work commutes (logit) and the trip length for automobile and transit trips (linear regression).

DATA

An initial list of thirty-six variables was compiled based on a thorough review of previous studies. This literature review informed the choices of what variables would be measured and at what level. It should be noted that some variables that are common in some studies in the U.S. were omitted in this study. These mainly concern race and school performance. It is also important to note that the choice of variables included examining variables that have been shown in the literature to correlate with either travel behaviour *or* residential location decisions. Song and Knapp's, *Internally Connected, No Commercial, with a Touch of Open Space: The Neighbourhoods of New Homes in the Portland Metropolitan Area* (2004) was a key source for variable choice. Other important sources were Wilson et al (2004), Krizek (2003), Cervero (2002), Limtanakool, Dijist et al. (2006) and Coffey and Shearmur (2001).

A comprehensive list covering land use, demographics, and accessibility and proximity issues was generated; all of these were measured at the grid cell level. Later, the surrounding grid cells were included in the analysis. As will be shown below, it is important to note that the Factor analysis removed those variables that were not shown to significantly explain the observed differences in cells.

The goal at this stage was to compile a set of data that would explain the differences between neighbourhood types. Efforts were made to collect a wide range of variables. Not limiting the research to solely land-use or accessibility or demographics helped to make the study a powerful tool in describing regional variation in neighbourhood types.

LAND USE AND ENVIRONMENT

The area in each cell with the following land uses was measured: open space, park, commercial, residential, industrial, institutional and water. This layer provides a good base layer for the more specific data to follow. The above land use categories are quite general and the expected influence on travel would be quite obvious. A mix of residential and commercial/employment uses would be expected to correlate with a reduction of both car usage and trip length. The inclusion of the land uses of water and parks is simply to achieve a deeper understanding of the neighbourhood types.

FAMILY STRUCTURE/ DEMOGRAPHICS

Information on income and family structure was collected using Canadian Census data from 2001, the closest census to the 2003 Origin-Destination survey. This category included the variables: average household size, average number of children, median household income, average number of bedrooms, and average number of rooms.

An increase in any of these variables is thought to increase both the likelihood of car use and household VMT (Frank and Pivo 1994; Crane 1996; Cervero and Kockelman 1997; Badoe and Miller 2000; Crane 2000; Ewing and Cervero 2001; Cervero 2002; Handy, Cao et al. 2005).

An explanation given by van de Couvering and Schwanen (2006) is that for larger households the car offers much better "space-time flexibility" and perceived safety, particular in relation to biking, for families with small children (van de Coevering and Schwanen 2006).

Accessibility and Proximity

Accessibility to public transit was initially measured in several ways. First, a count of the number of metro stations and commuter train stations in the cell, secondly cells with their centroid within 800 meters of a station were deemed to be "accessible". As bus stop data were only available for the island of Montréal, two proxies were used, a dummy variable for "Bus route in Cell" and a count of the number of bus routes. It should be noted that this count does not take into account the actual number of buses that go through a particular cell per day or at what time. This could be useful in future studies. Many studies have highlighted the importance of accessibility to transit in predicting use (Tsai 2008).

Urban Form

Related to the issues of accessibility above, the length of train track in each cell was also measured. In addition, the total lengths of road, as well as the separate length of local roads, major roads and expressways were also measured. This is to account for the obvious differences between the character of a cell with 200 metres of low-speed local street versus one with 200 metres of highway. These variables were selected as they have been shown to impact residential choices. In addition, the census provided variables on the number of various dwelling types and year of construction.

Notes on Data

The census data is, by its nature, aggregate. However, particularly for population characteristics, efforts have been made to optimize accuracy. For example, population estimates were performed in GIS by intersecting residential land use with the grid cells, in this manner, the percentage of residential land-use in any given cell could easily be calculated. In other words, the process does not presume that the population is evenly spread out through the census tract, parks, water, industrial and other non-residential land are removed from the analysis of population characteristics.

In addition, variables such as average rent, average value, bedrooms etc were calculated as a weighted average for cells that straddle more than one census tract and were given zero values for those parts of census tract entirely in water, park or open land.

Figure 4 show the importance of examining neighbouring cells. While the highlighted cells in each group might have similar characteristics, the great variation in the neighbouring cells will give the cells their different cluster characteristic. Each group is similar in one aspect, commercial, residential or street characteristics. However, a simple look at the surrounding cells make it apparent how important it is to look at the context. In the first group for example, the two middle cells might have an identical amount of commercial activity but their surrounding cells differentiate them easily.

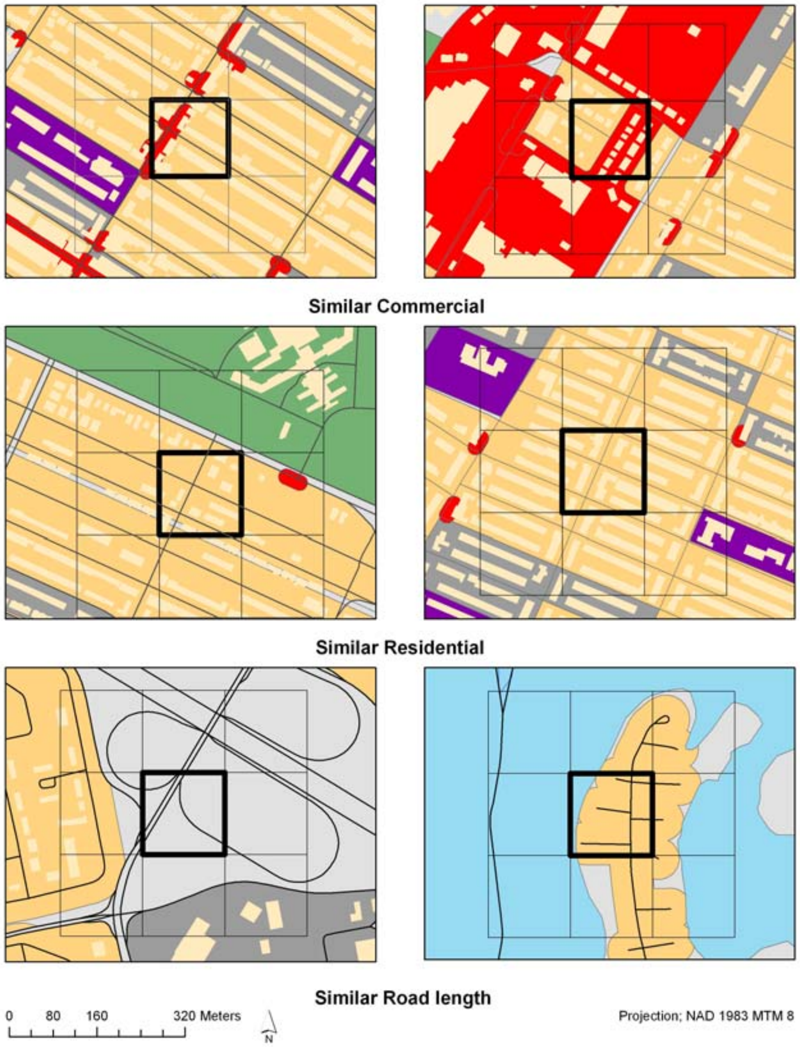

Figure 4: Importance of looking at Surrounding Cells

Of course, this simplified diagram only shows one variable – land use or street length – at a time. In practice this process looked at dozens of variables simultaneously.

INDIVIDUAL AND HOUSEHOLD DATA

This experiment makes use of several data sources with varying degrees of aggregation. On a totally disaggregate level, information on the individual traveller is known from the O-D survey. The variables used in the final regression are the age and gender of the individual, number of people in household, number of trips by the individual, number of trips made by the household and the start time of the trip. The O-D survey also provides precise X and Y coordinates for both ends of the trip. In addition to using this as the basis of the Factor and Cluster analysis, data on trip length is also calculated from this dataset. A schematic of the structure of the experiment is shown in Figure 5.

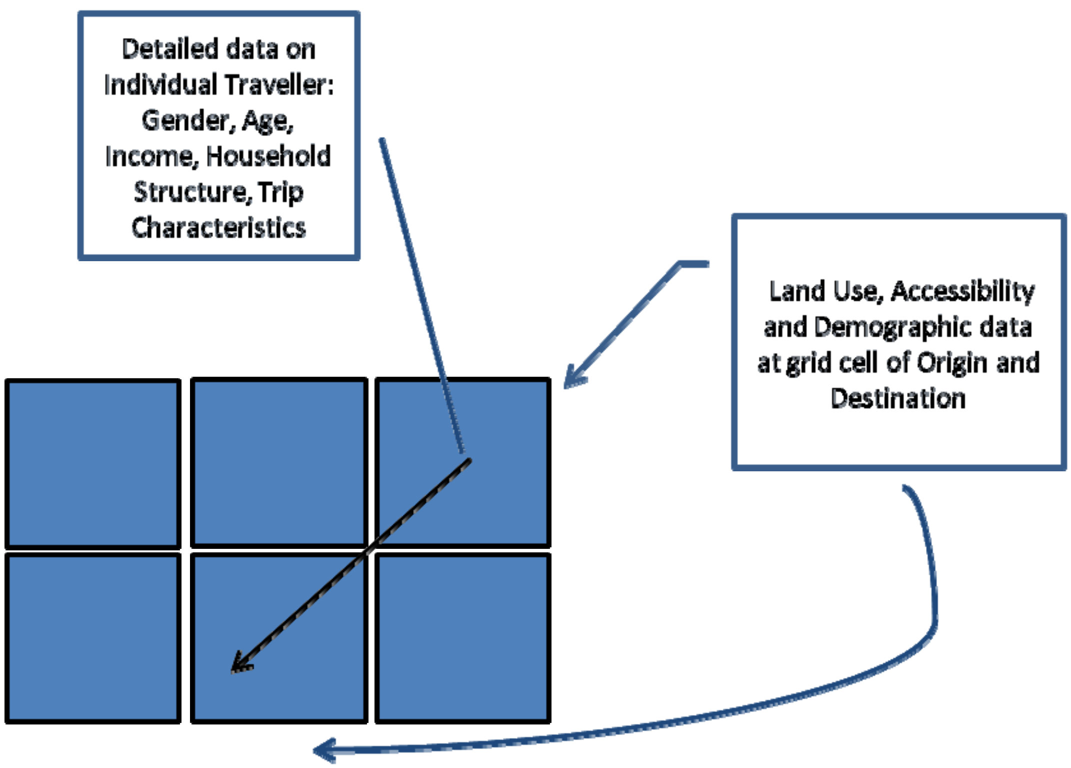

Figure 5: Schematic Diagram to show the basic design of the experiment.

Factor and Cluster Analysis

General

Factor Analysis has one chief goal: to describe the covariance among many variables in terms of a much smaller number of underlying random quantities that are referred to as factors (Johnson, Wichern, 1988). In other words, the analysis works to extract a smaller number of factors from a large data set, while keeping the meaning and significance of the full data set. For this reason, it is often referred to as a data reduction technique. This quality makes the technique most desirable for this research. It would be unwieldy, if not impossible, to run the desired regression analysis with the full set of 127 land-use and demographic variables at the point of origin and destination.

Another key feature of this approach is that it does not make any assumptions regarding geography. This is an important part of this study as no assumptions are made that areas near each other are necessarily more similar than areas quite distant. The goal is to find those grid cells that are the most similar to each other regardless of location. However, spatial location will be dealt with dummy variables and the dispersal of each cluster will be explained.

After an initial Factor and Cluster of all 223,000-grid cells was seen to be lacking in the level of desired detail, two solutions were attempted. First, all grid cells that were 100% Open land or Water were removed from the grid cell analysis (they were however kept for the purpose of the neighbouring cells). This result still lacked much of the detail that was needed in the analysis. See Figure 6.

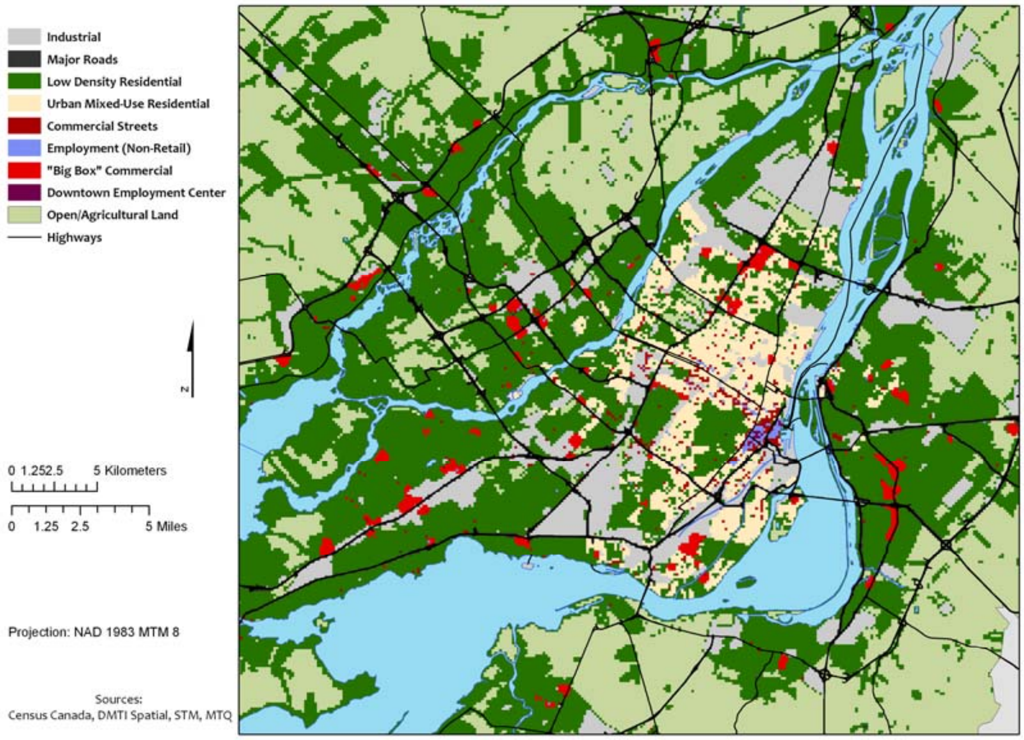

Figure 6: Original Factor and Cluster Map

The solution presented here was to run a separate Factor and Cluster analysis on Home and Work locations. In this way, the 19 000 grid cells that are home to a traveler of which data is available from the O-D survey and the 9 200 cells that represent work locations were analyzed separately. A different set of variables were shown to be significant for each process resulting in a map that clearly shows differences between residential and work-place locations throughout the region. While this type of analysis can have drawbacks, notably in researcher subjectivity, the results shown here are thought to a useful way in which to understand regional urban form and settlement patterns.

HOME LOCATIONS

The first Factor analysis will look at the 19 879 residential cells in which Home to Work travel is known. From an initial inputting of over 100 variables at the grid cell and neighbouring cell level, 67 variables were shown to significantly explain variations in neighbourhood types. This includes 33 variables at the grid cell and neighbouring cells plus distance form downtown. From these 15 factors were extracted that jointly explain over 80% of the variation between cells.

The challenge of Factor analysis is in interpreting the results. The researcher must make meaningful decisions about the implication of each factor based on the examination of which variables are the most heavily loaded. In this case, the Factors were relatively easy to interpret, as each was defined by a consistent set of variables. It is worth noting that in the vast majority of cases, the variable measured at the cell level and neighbouring cells were found to be in the same factor. In a smaller number of cases, a cell-level measurement was seen to be different from its surroundings, this is seen as strength in this analysis as, for example cells with a high degree of retail within them are separated from cells that are adjacent to heavy commercial activity.

Before presenting the factor analysis, descriptive statistics on each variable are shown in Table 1. Note that DMTI refers to DMTI Spatial Inc.; Stats Can refers to statistics Canada, the body in charge of the Candian census. This Table only presents the data at the cell level. The Factor and Cluster also looked at the surrounding cells, meaning that there are twice as many variables in the analysis.

Factor One is dominated by the variables capturing population density in the form of total population, number of dwellings, number of workers, and number of university graduates. It was thought the Factor analysis might separate areas of socio-economic difference as measured by levels of education; however, this was not the case. This factor also includes the variable for proximity to downtown.

Factor Two, in contrast is characterized by household information and captures large homes and large families measured by the number of rooms, bedrooms, and children.

	Variable	Source	Unit	Min	Max	Mean	Std. Dev
Land Use	Commercial	Census	Percent of Cell	0	99.18	1.724134	7.765
	Commercial Land Use	DMTI	Square Metres	0	440038.88	3639.8808	22998.987
	Park Area	DMTI	Percent of Cell	0	100	3.3557146	11.703
	Government and Institutional	DMTI	Percent of Cell	0	100	3.5842331	12.496
	Industrial and Resource	DMTI	Percent of Cell	0	100	6.3912581	16.935
	Water	DMTI	Percent of Cell	0	95.71	0.8075457	5.690
	Golf area	Census	Square Metres	0	22500	52.664421	794.275
	Length of train tracks	STM	Metres	0	1171.35	5.9359515	52.189
	Length of Highway	DMTI	Metres	0	949.73	14.169664	61.893
Employment	Manufacturing Jobs	Stats Can	Count	0	9	0.151662	0.574
	Number of Workers	Stats Can	Count	0	611.088	51.440953	47.854
	Unemployed	Stats Can	Count	0	167.6122	4.620375	7.046
	University degree	Stats Can	Count	0	747.616	21.591696	32.999
	High school Graduate	Stats Can	Count	0	240.6913	12.228744	11.242
	Trade school	Stats Can	Count	0	100.262	7.4732465	6.550
Housing and Demographics	Total Population	Stats Can	Count	0	1164.7095	106.33941	101.839
	Number of Dwellings	Stats Can	Count	0	900.9044	45.764314	51.819
	New Construction	Stats Can	Count	0	37.2129	1.4896344	2.251
	Pre-46 Dwellings	Stats Can	Count	0	412.739	7.7249085	20.878
	Apartments	Stats Can	Count	0	910.3637	31.483092	53.185
	Owner Occupied Dwellings	Stats Can	Count	0	462.1197	19.633862	12.954
	Rented Dwellings	Stats Can	Count	0	873.7252	26.098084	44.290
	Average Number of Bedrooms	Stats Can	Count	0	4.2	2.5069128	0.581
	Average Number of Rooms	Stats Can	Count	0	10.2	5.9966037	1.289
	Average Number of Children	Stats Can	Count	0	2.4	1.1135867	0.239
	Average People per Household	Stats Can	Count	0	3.9	2.9129069	0.438
Service	Distance from Downtown	NA	Metres	335.41	63000.36	17827.489	10805.002
	Access to Commuter Train	STM	Dummy	0	1	0.0551336	0.228
	Restaurants	EPOI	Count	0	9	0.0845616	0.581
	Retail	EPOI	Count	0	9	0.139153	0.797
Econo.	Average Dwelling Value	Stats Can	CAD	0	1493663	241688.14	108028.108
	Average Rent	Stats Can	CAD	0	1468.0094	584.53763	159.907
	Median Household Income	Stats Can	CAD	0	234528.16	59493.055	19622.081

Table 1: Descriptive statistics for residential cells

Factor Three includes the three variables meant to account for wealth and expensive real estate. It includes average home value, average rent and median household income at both levels – cell and neighbours. The fourth factor includes two variables, at both levels to account for commercial activity. This variable is measured as the total area in square meters of land uses devoted to commercial activity within the cell. Factors five and six are characterized by retail and services in the cell and surrounding cells respectively. The difference between these two factors is important and will be examined further.

Factor Seven captures the presence of parks and golf courses in and surrounding the cell. Factors eight and nine measured industrial land use and commuter rail train access respectively. Factors ten through fourteen each measure one variable at both levels: new construction, institutional land use, degree of water frontage, and presence of train tracks and highway respectively. The last factor captures the degree to which residences are owned.

Factor	Variables
Population Density	Apartments
	Dwellings
	Owned
	Rented
	University
	Trade School
	Unemployed
	Employed
	High School
	Population
	Distance
Household Structure	Rooms
	Bedrooms
	People per Household
	Children
Income/Housing Value	Rent
	Value
	Income
Commercial Activity	Commercial Land Use
Retail	Retail
	Manufacturing Jobs
	Retail
	Restaurants
Services Nearby	Retail Nearby
	Restaurants Nearby
Parks/Golf	parks
	Golf Courses
Industrial	Industrial Land Use
Commuter Train	Access to Commuter Rail
Newer	New Construction
Institutional	Government and Institutional
No Water	Water
Train Tracks	Train Tracks
Highway	Highway
Owned	Owned

Table 2: Variables in each Residential Factor

Table 2 lists the factors with all variables, complete factor loadings can be found in Appendix I. Note that each of these variables was measured at both the cell and surrounding cell level. The residential factor and cluster analysis therefore utilized sixty-seven variables, thirty-three at both the cell and surrounding cell level plus distance from downtown, which was only measured at the cell level as there would be little to no variation in the cell distance and the average of the neighbouring cell distance.

The goal of using cluster analysis is to further refine the neighbourhood types regardless of spatial location (Song and Knaap 2004). K-means cluster analysis is used to facilitate this. The process sorts each cell into one of a pre-determined number of clusters such that internal similarity is maximized while similarities between groups are minimized.

The optimal number of Cluster categories extracted from the fifteen factors was found to be ten. Although this resulted in one very small cluster, the overall effectiveness of this analysis far outweighed the use of nine or fewer factors. Other amounts were found to not adequately describe differences in urban form. Local knowledge of the region was useful in understanding the clusters as is often the case in this type of analysis.

Each Cluster has – positive or negative – inputs from each factor; these are then used to understand the characteristics of the cluster. Below are the names and a brief description of each cluster. These will be mapped and graphed in much detail below. Figure 7 shows a graph of cluster Centroid values.

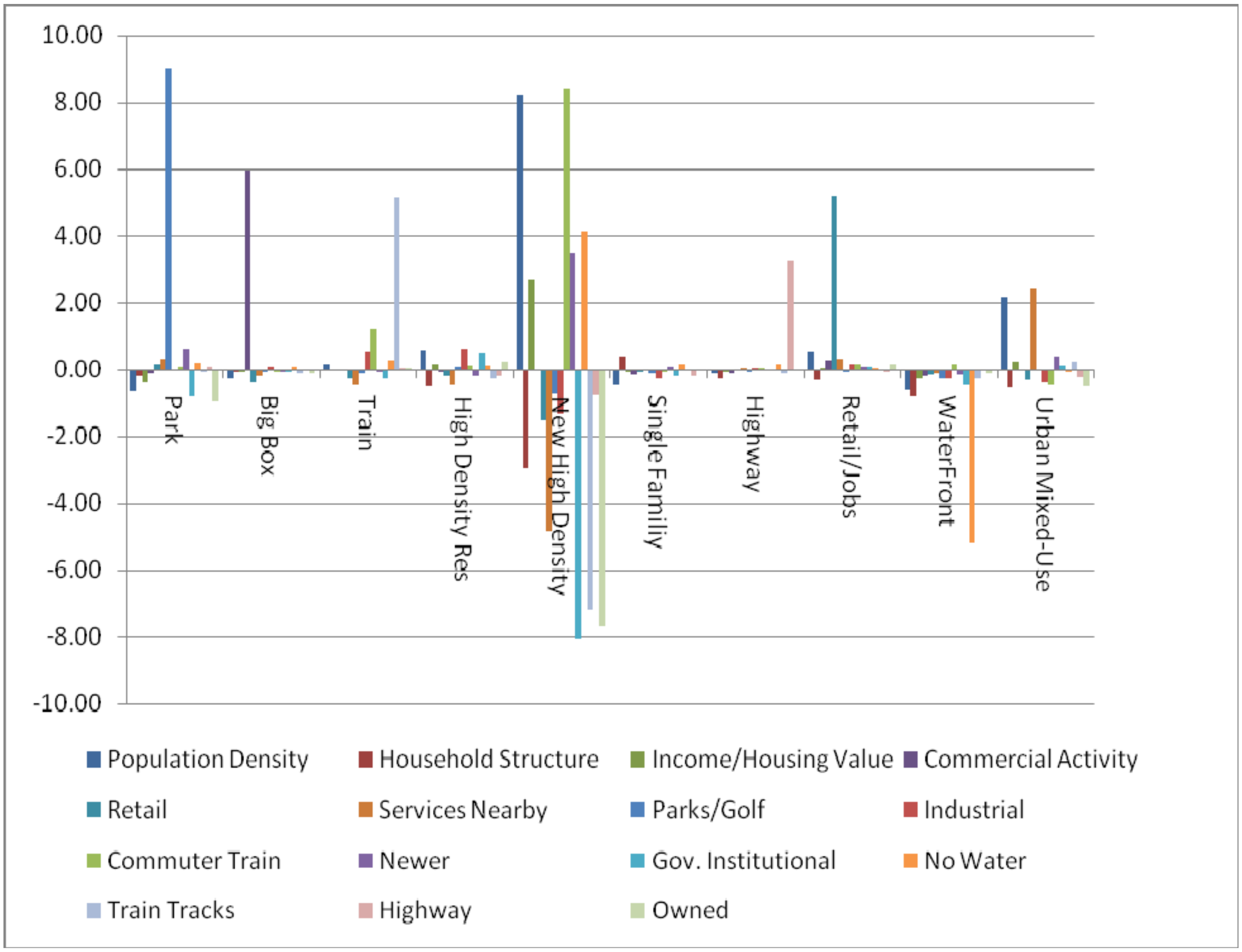

Figure 7: Cluster Centroid values

1 *Park areas.* The factor capturing park land and golf course is by far the biggest contributor to this cluster, however, the second highest input capturing new construction helps make sense of this group, newer residential areas fronting on parkland.

2 "*Big Box Commercial*". Again, with only factor overshadowing all others, this cluster is relatively easy to interpret. Noteworthy absences include; retail and highway, this helps to differentiate between commercial streets with a higher concentration of small-scale shops with good accessibility.

3 *Commuter Train Access*. with three positive inputs, train tracks, commuter rail stations and industrial land, this cluster corresponds with areas of high accessibility to the commuter train system.

4 *High Density Residential*. Characterized by population density and smaller household size, perhaps most importantly it is negative in retail and services, easily differentiating itself from the urban mixed use category below.

5 *Newer High Density with poor retail access*. This small cluster is characterized by newer high density residential with poor access to commercial activities (note: this cluster is much smaller than would be desired in Cluster analysis, however, the use of less than ten clusters failed to capture the desired variations in urban form)

6 *Single Family Residential.* While the graph might be initially difficult to interpret, an examination of the positive inputs makes this cluster clear, with positive inputs from household size, new construction, and the "no water" factor as well as negative contributions from the retail services category; this is clearly single family homes with poor retail access, the suburbs in other words. Not surprisingly, this is the largest of the ten clusters, comprising roughly half of the residential clusters. Again, it is important to note that not all of these grid cells are located geographically where one might be tempted to assume. While they do tend to be farther away from downtown on average (see spatial distribution section below) there is a wide dispersion of these cells both on and off the island.

7 This cluster is characterized by proximity to *highways* and retail services.

8 *Commercial Streets*. Here the mapped output was quite helpful in defining the cluster. It corresponds with Montréal's main commercial streets such as St-Laurent and St-Denis. It could also be thought of commercial/residential mixed-use as opposed to Cluster ten below

9 This cluster clearly describes *waterfront property* throughout the region.

10 *Urban mixed use*. interestingly, while 4, 8, and 10 share many of the same factor contributions, their relative strengths make their differences clear. This cluster is dominated by high density residential with retail services nearby.

Additional Geographic and Descriptive Analysis of Residential Clusters

Table 3 shows population, dwelling and density measures for each cluster. Interestingly, a high percentage of the total population of the region is accounted for in the cells in the final analysis. Also, as would be expected, this clearly shows the difference between the population and dwelling densities of the various clusters. Waterfront and Park front areas have by far the lowest residential density, predominantly single-family areas have a population and dwelling density roughly one third that of High density urban; the difference between the Urban Mixed Use cells is even more dramatic.

	Total Cells	Area (Km)	Population	Density
Park	138	3.1	4960.1	1597.5
Big Box	373	8.4	31322.6	3732.2
Train	385	8.7	45908.4	5299.7
High Density Res	5232	117.7	812120.7	6898.7
New High Density	6	0.1	925.3	6853.9
Single Familiy	10770	242.3	695717.5	2871.0
Highway	1045	23.5	100067.1	4255.9
Retail/Jobs	500	11.3	87234.2	7754.2
WaterFront	462	10.4	15344.2	1476.1
Urban Mixed-Use	972	21.9	320321.1	14646.6
Total/Average	**19883**	**425.5**	**2113921.1**	**5538.6**

	Children	People	Bedrooms	Landuses	Value of Dwelling
Park	0.9	2.4	2.2	2.5	$213,941
Big Box	1.1	2.8	2.4	2.8	$251,095
Train	1.1	2.9	2.3	2.3	$275,407
High Density Res	1.0	2.7	2.1	2.3	$283,800
New High Density	0.8	2.6	1.9	4.0	$236,910
Single Familiy	1.2	3.1	2.8	1.7	$218,407
Highway	1.0	2.8	2.4	2.5	$226,035
Retail/Jobs	1.0	2.7	1.9	3.2	$274,275
WaterFront	1.0	2.6	2.3	2.7	$199,859
Urban Mixed-Use	0.9	2.7	1.7	2.6	$279,903

Table 3 Demographic Analysis of Residential Clusters

Note: Densities are given per square kilometr*e*.

In Table 3, demographic information for each cluster is given. Again, the differences between clusters are striking. While average home value is, somewhat surprisingly, relatively constant, the other variables tell an interesting story. Single-family areas have the highest average number of children, people per household, number of rooms, number of bedrooms, as well as the lowest number of land-uses. These are shown as these variables have been shown to both influence residential choices and travel behaviour.

The final descriptive figure for the residential clusters concerns their spatial distribution, while this can also be seen to some extent on the cluster map (Figure 8), Table 4 clearly shows how each cluster is geographically located. While urban mixed use, high density residential, retail and job centers are overwhelmingly located on the island, single-family and waterfront areas are located off-island. However, it is also noteworthy that there are, in fact several dozen high density residential and a handful of urban mixed use cells located off-island. Average distances from downtown and standard deviations are also given. This information, along with the maps gives a highly detailed description of the distribution of land uses, built form and demographic information throughout the region.

	Island	**Laval**	**South Shore**	**North Shore**	**% Off-Island**	**% On-Island**
Park	35	18	57	28	74.64	25.36
Big Box	194	29	99	51	47.99	52.01
Train	210	38	40	97	45.45	54.55
High Density Res	4017	370	719	126	23.22	76.78
New High Density	6	0	0	0	0.00	100.00
Single Family	1972	1664	3336	3798	81.69	18.31
Highway	423	132	237	253	59.52	40.48
Retail/Jobs	410	26	40	24	18.00	82.00
Water Front	130	83	64	185	71.86	28.14
Urban Mixed-Use	955	2	11	4	1.75	98.25
Total	**8352**	**2362**	**4603**	**4566**		

	Average Distance	**Standard Dev.**
Park	17563	9184
Big Box	14313	8651
Train	13007	10578
High Density Res	9324	4681
New High Density	8551	0
Single Family	22266	9263
Highway	14618	9513
Retail/Jobs	6472	5938
Water Front	23362	9369
Urban Mixed-Use	4437	2542

Table 4 Geographic Dispersion of Residential Cluster Cells

As established earlier, Montréal is not a mono-centric city; however it is interesting to note the spatial dispersion of the clusters from downtown. These distances are measured from an "assumed downtown", a point near the corner of Peel and René Lesvesque.

The combination of the factor and cluster outputs; demographic and geographic data; as well as the regional and inset maps should give the reader a clear picture of the difference between these ten residential clusters. Figure 8 and Figure 9 show the grouping of the clusters in a regional and close-up view respectively.

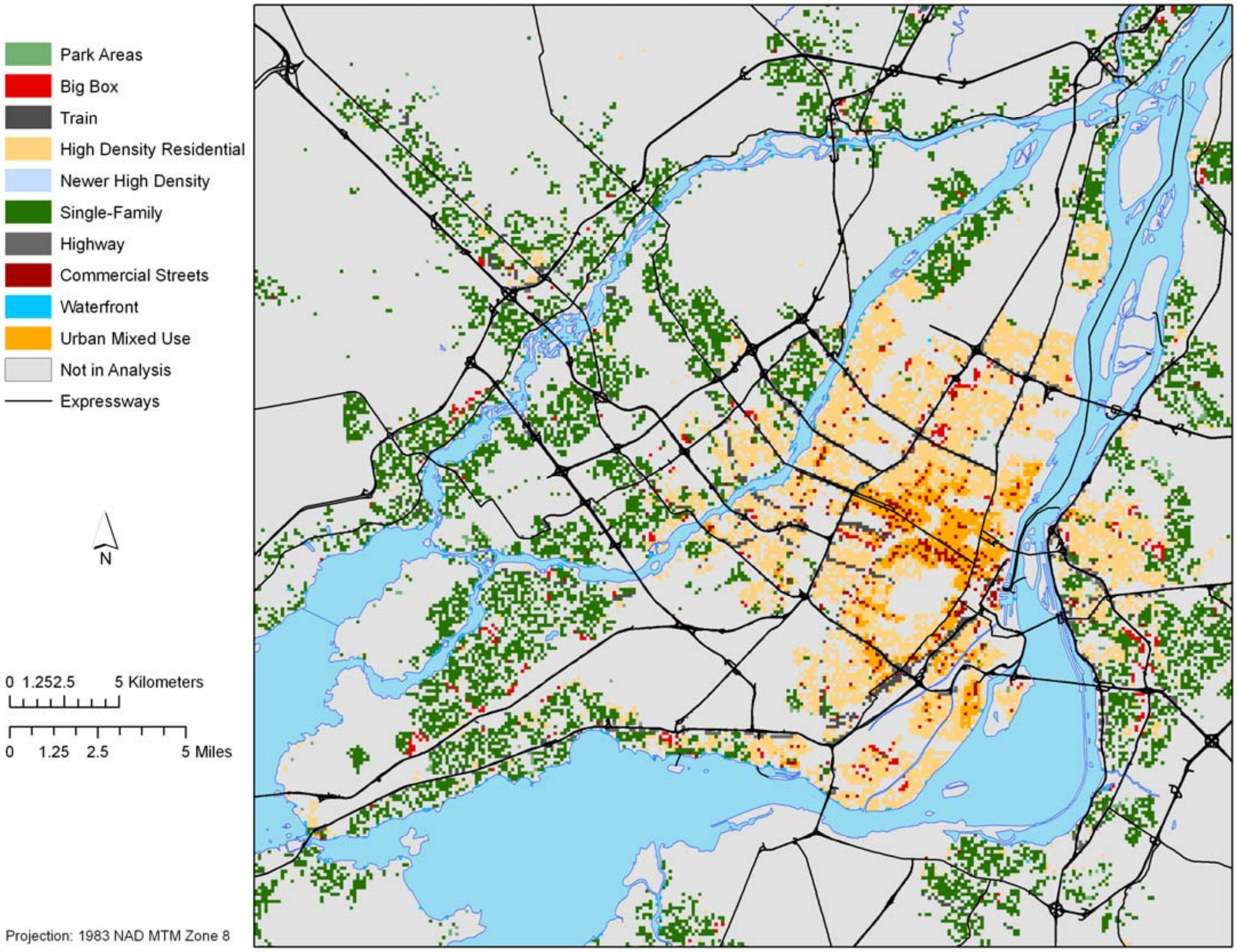

Figure 8: Home Location Cluster Map

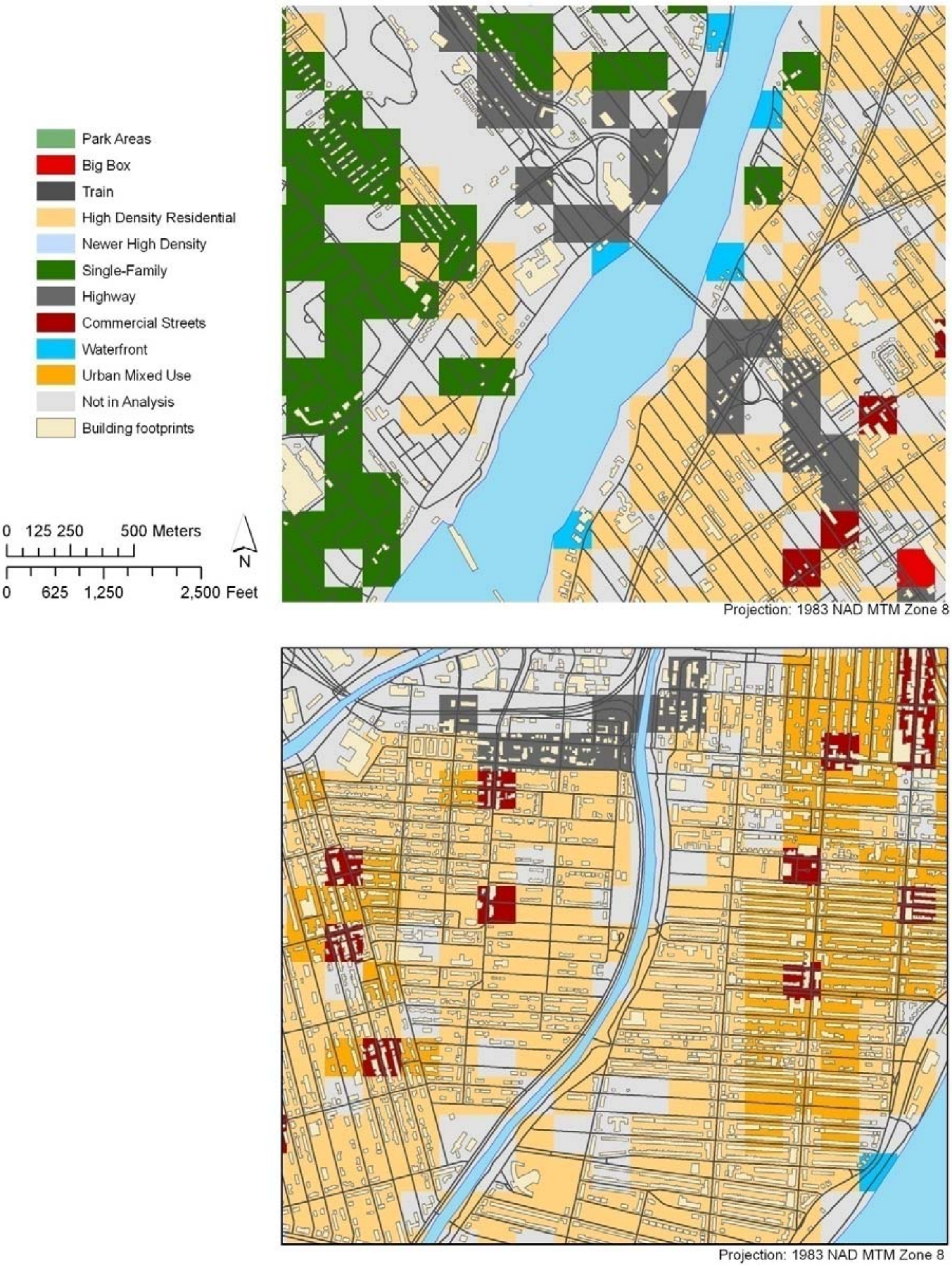

Figure 9: Close-up comparison of Home Location Cluster Cells

It is useful to zoom in a few areas to highlight the level of detail that this process was able to generate, (Figure 9). There is a clear distinction between grid-based patterns and more curvilinear patterns in the top map where the residential area to the west are identified as single-family and the higher density areas to the east are dentified as high density residential. More importantly, especially in the bottom map, the more densely populated areas of Verdun are contrasted from less dense areas; in addition waterfront areas and commercial are clearly seen. Also the areas around major highway infrastructure are clearly visible. It is also clear that not all grid cells that touch water are automatically included in the waterfront category, the totality of factor contributions lead to the final cluster grouping.

WORK LOCATIONS

For the purposes of this analysis, it was then necessary to repeat the process for the 9000 grid cells that are a destination for a known trip in the O-D survey. While the same variables were initially inputted, the process showed different variables to be significant in explaining the variation between work cells. A brief description of the factor analysis and cluster results is given below. The Appendix I contains the full factor loadings. First, descriptive statistics are given for all variables in all 9,034 grid cells (Table 5). The work location factor and cluster analysis includes thirty-six variables at both levels plus distance for a total of seventy-three variables. As with the residential analysis, fifteen factors were extracted from the factor analysis.

Factor one is made up a variables that describe pre-1946, mostly residential areas capturing variables such as population and dwelling density.

Factor two is a bipolar factor as it has both positive and negative loadings, negative for industrial land use and positive for those variables that capture single-family neighbourhood characteristics. Some of these variables include residential land use, number of children, average number of people per household, median income, and average value of dwelling. This clearly makes this a factor to describe non-industrial residential areas with predominately-larger homes.

Factor three captures commercial land use, but not job or retail concentrations. Factor four corresponds to highway length and bus service. As mentioned above, the bus variable was captured by the length of bus lane in the cell not as a count of actual bus stops. The major input of the fifth factor is the length of local roads; the total length of roads (which includes local roads) makes a less significant input.

The next two factors comprise parks and golf course, and commuter train service respectively. The eighth factor captures residential areas with three separate measurements, amount of residential land use and the number of single-detached homes in the cell and surrounding cells. Open space at the cell and neighbouring level comprise factor nine. Factor ten is made up of three counts of job at the census level, total jobs, manufacturing jobs and management jobs. In contrast, factor eleven includes the total number of retail and professional jobs. It is important to note that, as an accurate point file was not available, these employment numbers were only available at the census tract level.

Factor twelve describes Institutional and government land use, while thirteen counts service accessibility in the form of a count of retail and restaurants in the cell. In addition, the last two factors describe waterfront areas and newer areas respectively.

	Variable	Unit	Source	Min	Max	Mean	Std. Dev
Transit	Commuter Train Acces	Dummy	STM	0	1	0.0817	0.274
	Length of Train Tracks	Metres	STM	0	1171.35	8.0475	60.554
	Bus Service	Dummy	STM	0	1	0.7013	0.458
Land Use	Commercial Land Use	Percent of Cell	DMTI	0	100	5.2864	14.860
	Government and Institutional	Percent of Cell	DMTI	0	100	7.4716	19.379
	Residential land use	Percent of Cell	DMTI	0	100	49.5	37.134
	Commercial land use attached to cell	Square Metres	DMTI	0	644818.1	11331.7	45449.251
	Water	Percent of Cell	DMTI	0	95.72	0.7764	5.706
	Park	Percent of Cell	DMTI	0	100	4.1273	14.317
	Open Space	Percent of Cell	DMTI	0	100	12.6515	23.103
	Golf area	Square Metres	DMTI	0	22500	87.2072	1152.876
	Industrial Land Use	Percent of Cell	DMTI	0	100	20.1841	32.270
Econ	Med. Household Income	Canadian $	Stats Can	0	234528	47455.7	27881.147
	Average Market Home Value	Canadian $	Stats Can	0	1493663	209636.6	138506.97
	Average Rent	Canadian $	Stats Can	0	1470.39	490.3	259.610
Housing	Owned	Count	Stats Can	0	154.96	13.1704	12.993
	Number of rented units	Count	Stats Can	0	873.725	24.5320	45.607
	New Construction 1996-2001	Count	Stats Can	0	34.3559	1.0706	2.059
	Construction pre-1946	Count	Stats Can	0	263.537	8.5844	21.330
	Number of Single detached homes	Count	Stats Can	0	65.8942	5.5624	6.479
	Number of apartments	Count	Stats Can	0	889.82	29.4901	53.009
	Total number of dwellings	Count	Stats Can	0	900.904	37.9055	54.493
Employ. and Services	Unemployed	Count	Stats Can	0	106.544	3.9416	6.893
	Workers	Count	Stats Can	0	611.088	39.7097	50.686
	Factories	Count	Stats Can	0	9.91667	0.5697	1.339
	Number of Managerial Jobs	Census Tract Count	Stats Can	0	8145	348.5573	625.523
	Number of Manufacturing Jobs	Census Tract Count	Stats Can	0	7845	701.1027	1456.623
	Number of Professional Jobs	Count	Stats Can	0	900	91.0811	146.295
	Count of Retail Jobs	Count	Stats Can	0	870	66.9924	123.600
	Number of Jobs	Count	Stats Can	0	9999	2614.4734	2203.519
	Restaurants	Count	EPOI	0	9	0.2595	1.022
	Retail	Count	EPOI	0	9.75	0.4730	1.423
Household	Average number of Bedrooms	Count	Stats Can	0	4.2	1.9649	1.008
	Average Children	Count	Stats Can	0	2.4	0.8863	0.450
	Average people per household	Count	Stats Can	0	3.9	2.3878	1.113
	Average number of rooms	Count	Stats Can	0	10.2	4.7533832	2.367
	Total Population	Count	Stats Can	0	941.89	82.79552	104.330
	University Graduates	Count	Stats Can	0	702.015	18.627969	35.991
Street Grid	Number of Intersections	Count	DMTI	0	39	4.705283	4.539
	Length of local roads	Count	DMTI	0	888.597	231.57778	152.309
	Road Length	Count	DMTI	0	1562.12	380.45465	189.587
	Number of Intersections	Count	DMTI	0	39	4.705283	4.538575
	Length of local roads	Count	DMTI	0	888.597	231.57778	152.3092
	Number of local roads	Count	DMTI	0	26	4.2484218	3.185795
	Highway in Cell	Dummy	DMTI	0	1	0.2380109	0.425889
	Highway Length	Count	DMTI	0	1181.2	56.971182	135.1145
	Distance from Downtown	Metres	DMTI	0	59759	15183.976	10579.98
	Valid N (listwise)	9043					

Table 5 Descriptive Statistics for all work location cells

Factor three captures commercial land use, but not job or retail concentrations. Factor four corresponds to highway length and bus service. As mentioned above, the bus variable was captured by the length of bus lane in the cell not as a count of actual bus stops. The major input of the fifth factor is the length of local roads; the total length of roads (which includes local roads) makes a less significant input.

The next two factors comprise parks and golf course, and commuter train service respectively. The eighth factor captures residential areas with three separate measurements, amount of residential land use and the number of single-detached homes in the cell and surrounding cells. Open space at the cell and neighbouring level comprise factor nine. Factor ten is made up of three counts of job at the census level, total jobs, manufacturing jobs and management jobs. In contrast factor eleven includes the total number of retail and professional jobs. It is important to note that, as an accurate point file was not available, these employment numbers were only available at the census tract level.

Factor twelve describes Institutional and government land use, while thirteen counts service accessibility in the form of a count of retail and restaurants in the cell. In addition, the last two factors describe water-front areas and newer areas respectively.

As with the residential clustering, the important information comes out in the clustering. Again, the analysis is undertaken on two levels, interpretation of the output graphs and confirming the meaning of the clusters on the mapped outputs.

Figure 10 shows the cluster centroid values, the predominance of one factor for most clusters, this makes interpretation easier. It is worth noting again that, while some of the names for the residential and work cluster are similar, there are important differences between them.

1 *Isolated Suburban Retail areas.* The first cluster is, in fact, one of the most difficult to make sense of. With high positive inputs from the park land use as well as the factor capturing both high levels of both retail and profesional employment, this cluster describes relatively isolated areas of employment in otherwise park or open space.

2 *Waterfront.* The measurement of water is by far the biggest factor in this cluster, a high score for highway makes this cluster job areas near highways and water.

3 *Mixed Use Commercial and Residential*

4 *Suburban office park,s* Isolated Retail and Commercial areas near parks and golf, higher input from the professional and retail job concentrations point towards.

5 "*Suburban*" areas. Although this cluster is negative in all factors that capture employment and services and positive in low-density residential factors, there are obviously some employment oppurtunities, as each cell is the destination of a work trip.

6 "*Big Box Commercial*" characterized by commercial land use near major roads, with positive (but small inputs of employment)

7 With the highest loading from the train accessibility factors, this cluster is labelled *Train*.

8 *High density residential mixed use*, similar inputs to Mixed Use Commercial, however three is more of a presence of residential. Near *commuter rail staions*, small but significant input from the service factor

9 *Instititutional and Government Job areas.*

10 Its four postive inputs suggest*, Employment Subcenters* easily accessible by highway.

Fifty-four percent of all work cells are located on the island, roughly 9% in Laval, with the remaining 37% essentially evenly split between the North and South shores. Figure 10 shows these cells in a regional view as well as a close-up on downtown.

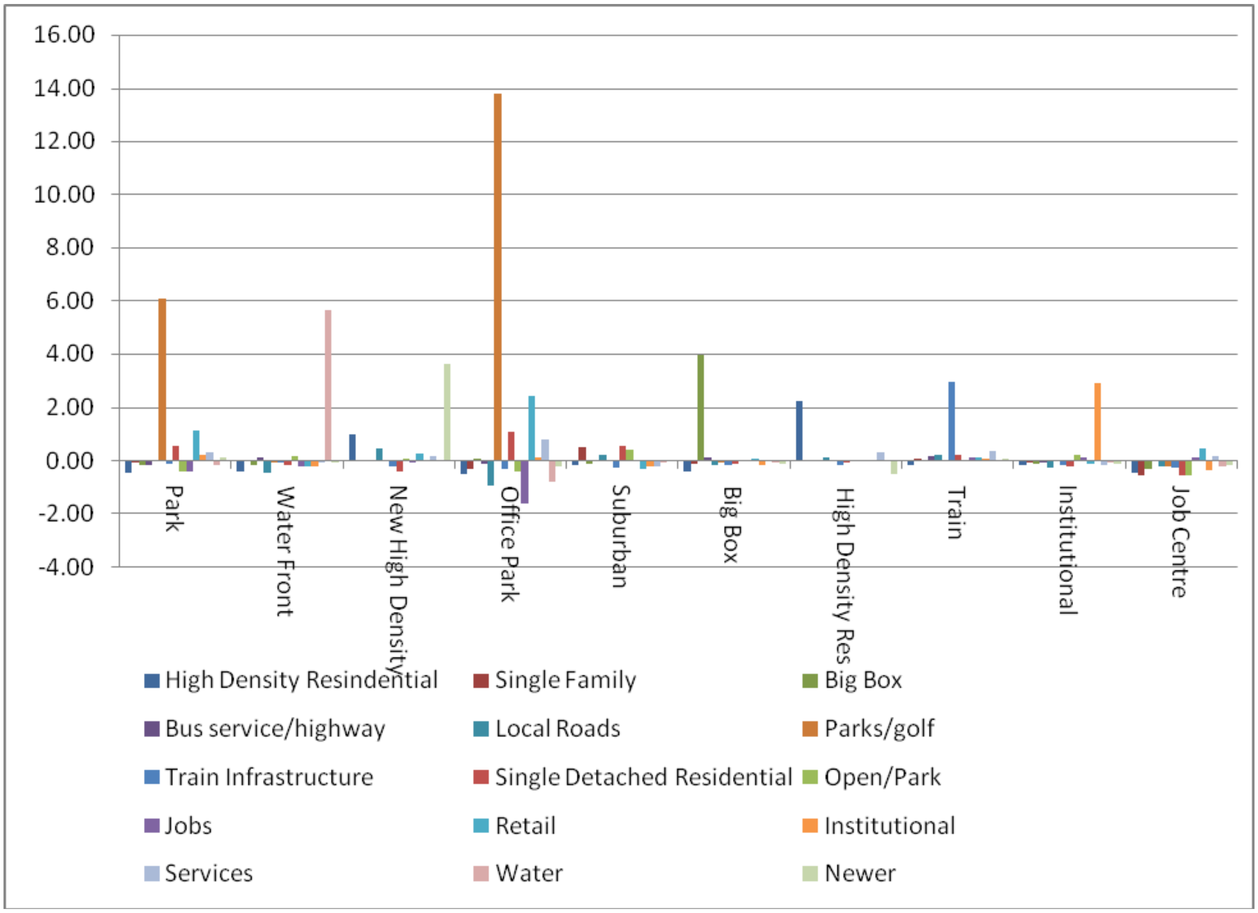

Figure 10: Work Location Cluster Centroid Values

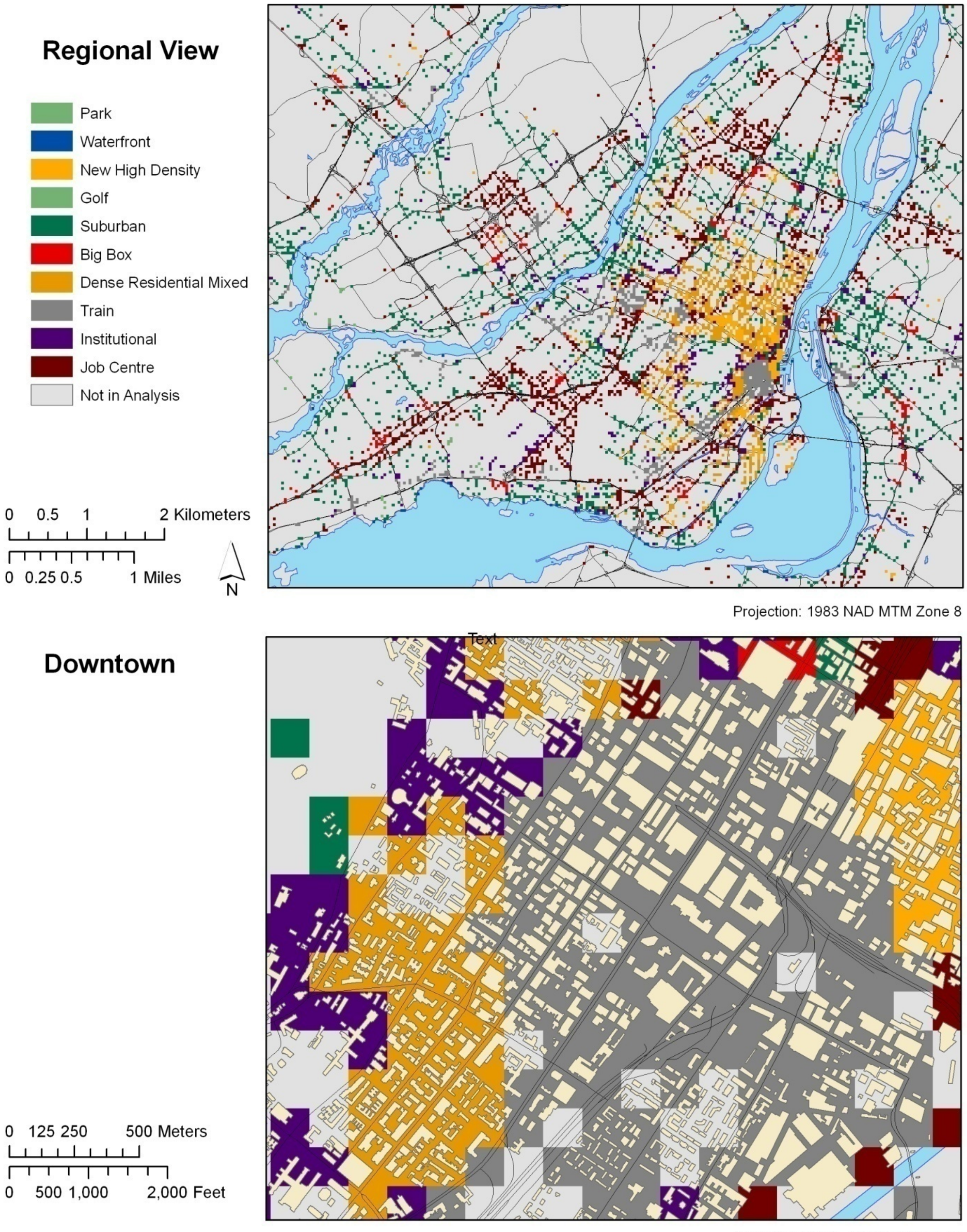

Figure 11: Work location clusters

While the work location map is not as easy to "read" as the residential maps, its usefulness will soon be shown. One close-up of downtown is presented below, clearly visible is the job concentration that easily accessible to train and transit, as well as the McGill University campus which can be seen in purple Institutional. Also shown are the mixed use area to the south-west of the campus and a few cells of Westmount, an upscale mostly residential area.

MAJOR FINDINGS

This section is divided into several sections. First, some general findings to describe Montréal regional commuting will be presented. This is itself divided into two sections, mode and trip length, which is presented in a geographic, demographic and cluster based manner. These findings will be helpful in understanding the more complex and thorough analysis that will address the issue of trip length.

MODE

Before moving on to the analysis of trip lengths, an analysis and discussion of mode choice will be presented.

GEOGRAPHIC

Having a clear picture of the nature of commuting in the region will be helpful in understanding the statistical models developed below. This study looked at home-to-work commuting trips that did not feature a major mode shift, from car to transit for example. Trips that used two different types of public transit, bus to metro, for example, were included. Of the 49,650 work trips that fit these criteria, the modal split is as follows, Car (driver or passenger) 77.15%, transit (all forms) 17.07% and active (walking or biking) 5.78%. Numbers available through Statistics Canada (Statistics Canada 2008) based on the 20% "long form" census questionnaire show slightly different figures (see Table 6), nonetheless, it is interesting to contrast the modal split for Montreal versus the rest of the province and Country.

While the automobile still dominates the commute, Montréal has a note-worthy use of alternative modes of transport, especially in comparison to many North American cities. Please see Appendix III for further breakdown by mode. While 23% percent non-car commuting would be impressive by itself by North American standards, looking at the sub-regions, it is even more so.

While transit and active modes of transportation play a significant role in the mobility in the region, it is worth noting the geographical differences in mode choice in different sub-regions (Table 6). For work trips that begin and end on the island, only 59% are by car. As expected, transit use declines dramatically off-island, particularly for intra-suburban trips.

	Canada	Quebec	Montreal	This Study
Car	80.04	78.23	70.39	77.15
Transit	11.03	12.82	21.42	17.07
Active	7.71	8.03	7.34	5.78

Geography	Car	Transit	Cycle	Walk
Home Island	61.3	29.7	2.0	7.0
Home Laval	87.3	9.9	0.4	2.3
Home South Shore	82.2	14.2	0.9	2.8
Work Island	67.5	25.9	1.5	5.1
Work Laval	89.7	6.3	0.6	3.5
Work South Shore	88.6	5.6	1.3	4.5
Live/Work Island	59.1	31.3	2.1	7.6
Live/Work Laval	85.0	8.0	0.8	6.2
Live/Work South Shore	88.1	5.1	1.5	5.3
Live/Work North Shore	90.5	1.6	1.3	6.7

Table 6 Geographical breakdown of modal split.

Demographic

There are also noteworthy differences between males and females. Women are much more likely to take transit to work than men; conversely men are almost twice as likely to cycle to work (see Table V Appendix III). As will be shown in the regression models, income is also highly correlated with mode choice. This can also be seen in Figure 12. While car and transit use are relatively similar for those in the lowest income bracket, a wide difference quickly grows as income rises.

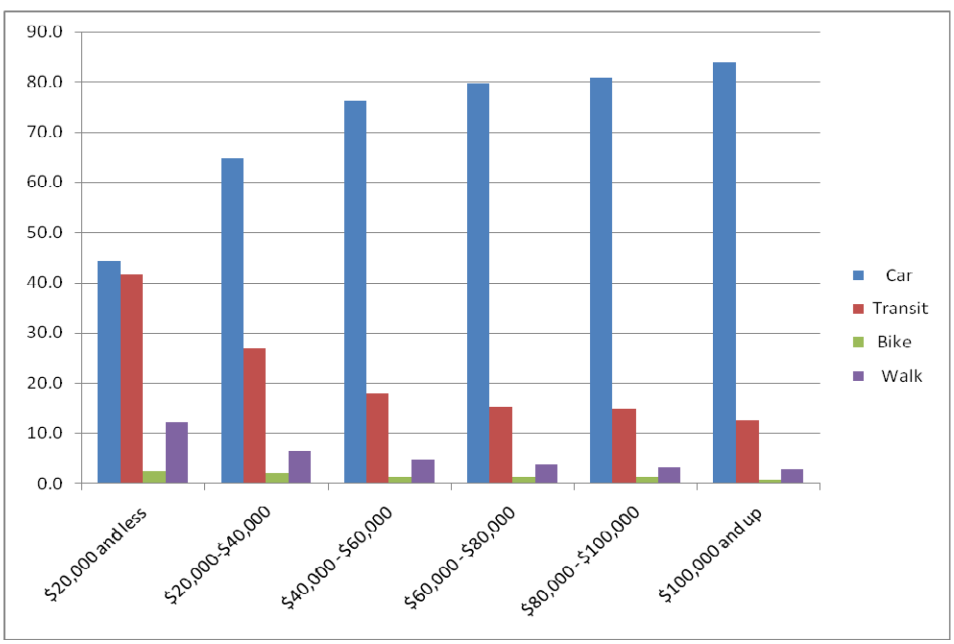

Figure 12: Breakdown of modal split by income

Some important findings include the fact that a full 9.6% of those who both live and work on the island use active transport, while the number is, a still impressive, 7% for Laval. In addition, car use for Montréal island residents is significantly lower than the regional average.

CLUSTER

This section will present a basic Cluster-based analysis. The small relative size of the New High Density Cluster makes interpreting trip length data from this cluster delicate. The preceding section served to present modal choice as a function of demographic and geographic characteristics, however, the focus of this research is on the relationship of the identified clusters and travel behaviour.

There are remarkable differences between the destinations of transit versus car trips. While areas of high train accessibility only make up 11% of car trips, they account for a full 31% of transit trips. In contrast, while suburban areas attract 24% of car trips, only 10.4% transit trips go there. This is illustrated in Table 7.

Origins	All	Car	Transit
Park	0.5	0.6	0.4
Big Box	1.7	1.7	1.7
Train	1.9	1.7	2.6
High Density Res	30.3	26.8	43.3
New High Density	0.0	0.0	0.0
Single Family	47.7	54.9	20.7
Highway	4.9	4.8	5.0
Retail/Jobs	3.1	2.3	6.3
Water Front	1.5	1.8	0.6
Urban Mixed-Use	8.5	5.5	19.5

Destination	All	Car	Transit
Park	0.2	0.2	0.1
Water Front	1.2	1.4	0.6
New High Density	5.0	3.9	9.0
Office Park	0.2	0.3	0.1
Suburban	21.6	24.5	10.5
Big Box	7.4	7.7	6.4
High Density Res	11.5	9.8	17.8
Train	15.7	11.4	31.8
Institutional	10.7	10.9	10.2
Job Centre	26.5	29.9	13.5

Table 7: Origins and Destination by percentage

Table 8 shows another telling example, percent of car trips for each origin and destination cluster.

Origin	Car %
Park	83.9
Big Box	75.2
Train	64.3
High Density Res	65.5
New High Density	75.0
Single Family	88.0
Highway	73.9
Retail/Jobs	47.7
Water Front	88.7
Urban Mixed-Use	42.6

Destination	Car %
Park	82.5
Water Front	85.6
New High Density	55.6
Office Park	89.5
Suburban	82.7
Big Box	78.2
High Density Res	60.1
Train	54.4
Institutional	74.1
Job Centre	87.0

Table 8: Car Modal Split

CAR COMMUTES BY CLUSTER

The following section gives a sense of the Origins and Destination for car work trips. The total number of trips that begin or end by cluster is given along with the percentage that that represents of all trips as well as the average distance of commutes. Not surprisingly, the vast majority of trips, 87% of all trips originate in the three clusters of single-family, urban mixed-use and high density residential; single-family areas alone account for roughly 54% of all trips. This, however, is simply a reflection of the number of cells in each cluster and the relative residential density; it tells us little without also examining the destination cluster information. This can be seen – in absolute numbers – in Table 9.

Average trips lengths vary considerably, trips from urban mixed use areas are approximately half as long as those from waterfront areas and single-family areas, and roughly a third less than park areas and the highway cluster. High-density and urban mixed-use have travel much shorter distances. This would seem to confirm assumptions about higher densities and travel behaviour.

Examining average cluster-to-cluster trip distances reveals more. The average length for urban mixed use and high-density residential and commercial streets is roughly half that of suburban, waterfront and park areas. In other words, residents of urban mixed use areas tend to live twice as close on average as those living in suburban areas.

Looking at the destinations, the most immediate difference is that the clusters contribute more evenly to the total count than was the case with the origins. Job centres and Suburban areas account for most of the trips, with Institutional areas, high density residential and train areas each contributing roughly 10% each. Though less striking than the differences between residential areas, it is worth pointing out that Job centers draw people in from the farthest distance. These ideas will be expanded upon below

The destinations of train, Institutional and job centre are shown to be the attracters with the longest trip length. This can be seen in Table 10. The destination distances do not tell quite so clear a story at first glance. While job centres exhibit the longest trips in which would seem to confirm basic economic theory of competition among workers, the other clusters are more difficult to read. High density residential, for example draw drivers from a greater average distance than the suburbs. While at first this might seem counter-intuitive, it is important to bear in mind that this might simply be capturing the “attractive” power of high density areas versus suburban, low density areas. We saw above that suburbanites do drive longer distances, the breakdown of cluster pairs will help to make sense of this.

	Park	Water Front	New High Density	Office Park	Suburban	Big Box	High Density	Train	Instit.	Job Centre	Total
Park	1	1	8	0	37	18	9	35	19	49	177
Big Box	0	3	17	0	141	55	52	54	58	159	539
Train	3	3	18	1	104	30	61	85	79	150	534
High Density Res	15	93	423	10	1746	616	1212	1120	973	2374	8582
New High Density	0	0	0	0	0	0	0	0	1	2	3
Single Family	42	273	520	70	4831	1449	1146	1813	1841	5573	17558
Highway	2	27	55	3	418	113	144	155	140	485	1542
Retail/Jobs	1	12	57	0	129	48	114	97	85	180	723
Water Front	2	22	16	1	176	43	35	60	57	163	575
Urban Mixed-Use	0	19	137	0	256	81	365	237	227	445	1767
Total	66	453	1251	85	7838	2453	3138	3656	3480	9580	

Table 9: Frequencies of cluster-to-cluster trips

	Park	Water Front	New High Density	Office Park	Suburban	Big Box	High Density Res	Train	Instit.	Job Centre	Average
Park	0	7247	14903	0	13332	15317	16840	18748	17872	15223	15756
Big Box	0	17360	14649	0	11239	10290	13444	14476	13682	13522	12757
Train	20417	17420	11994	3045	16833	11635	11642	10973	11643	15301	13652
High Density Res	14103	11846	9490	14225	10277	10290	7969	10651	10601	11905	10477
New High Density	0	0	0	0	0	0	0	0	10575	15084	13581
Single Family	10805	15057	22944	13516	13197	14802	23183	20009	19255	18319	17259
Highway	17055	13537	12696	3942	11409	11922	14304	13624	12813	15526	13438
Retail/Jobs	0	12416	6790	0	12285	11609	6281	8858	9866	12937	10264
Water Front	8511	15494	24922	5346	14295	18576	24515	16783	17565	20999	18027
Urban Mixed-Use	0	16558	4789	0	13532	11782	4327	7014	8651	12293	9092
Average	11784	14335	14924	13042	12486	13304	13703	15376	15352	16109	

Table 10 Average Distance Cluster Matrix

Cluster Combination	**Percent**	**Distance**
Single Family-Job Centre	17.4	18318.6
Single Family-Suburban	15.1	13197.21
High Density Res-Job Centre	7.4	11905.04
Single Family-Instit.	5.8	19255.43
Single Family-Train	5.7	20008.58
High Density Res-Suburban	5.5	10276.82
Single Family-Big Box	4.5	14802.45
High Density Res-High Density Res	3.8	7969.485
Single Family-High Density Res	3.6	23182.74
High Density Res-Train	3.5	10650.78

Table 11: The ten most common cluster-to-cluster combinations for home-to-work trips by car

Cluster Combination	**Percent**	**Distance**
Train-Office Park	0.003	3045.164
Highway-Office Park	0.009	3941.82
Urban Mixed -High Density res.	1.141	4327.004
Urban Mixed -New High Density	0.428	4788.96
Waterfront-Office Park	0.003	5346.107
Comm. Streets-High Density Res	0.356	6281.371
Comm. Streets-New High Density	0.178	6790.309
Urban Mixed Use-Train	0.741	7014.321
Park-Waterfront	0.003	7247.189
High Density Res-High Density Res	3.788	7969.485

Table 12 The ten shortest average car commute distances

Tables 11 and 12 tell an interesting story. Table 11 shows the ten most common cluster-to-cluster commutes along with their average distances and the percentage that these clusters represent of all trips. The most common commute is single family to job centre, this is also one of the longest average commutes at over 18 km. Most of these commutes have a long distance associated with them. Noteworthy is the length of high-density to high-density commutes with an average length of just 7.9 km. Table 12, on the other hand, shows the ten shortest commutes. In this we see that most of these combinations are also quite rare with the exception of high density to high density and urban mixed use to high density. In other words, the shortest distances by cluster combinations are, unfortunately, not common, while the most common combinations are, on average, quite long.

Remy Barbonnne (2007), in fascinating work on the Plateau, a gentrifying area of Montréal, found similar results. Whereas, residents of the area were predominantly working nearby in creative and technical sector jobs and walking, cycling and using public transit, most of the workers who worked the service jobs in the area were commuting longer distances, often by car. It is this in/out that must be considered in any discussion of the relative effectiveness of any land use policies to combat car usage and emissions. This will be discussed further below.

CAR STATISTICAL ANALYSIS

To better understand and analyse much of the above information, a multi-variate linear regression model was developed with length of trip as the dependent variable and the individual, household, cluster and geographical data as independent variables. The goal of multi-variate regression analysis is to understand the relationships between several *independent* variables and a *dependent* variable, here trip length. The results are shown below. The results are interesting and point towards the usefulness of this approach.

Two models are presented here: a “base” model that only looks at demographic information of the individual and household, and an “expanded” model that includes dummy variables for home and work cluster as well as geographic variables. While the basic model performs poorly (with an R Square of .061), the sign and magnitude of the variables is educational. The expanded model performs much better and gives important insight into regional travel behaviour as seen in Table 13. The increase in the R square – from .061 to .392 – resulting from the addition of the cluster and geographic variables shows the importance of using these non-demographic variables.

The results of the preliminary regression were as expected. Total number of trips by household, total number of trips by individual, low income dummy, and age squared all had a negative coefficient. In addition, and slightly more surprising, the AM peak dummy sign was also negative, perhaps suggesting that the AM peak congestion cost in time is having an effect on trip lengths, with commuters either making longer trips at other times of the day or taking other modes for longer peak-hour commutes. The variables that capture household size, wealth, number of cars, full-time status and age were all positive.

The origin clusters of park, big box, train, highway, single-family, and waterfront were all shown to be significant at the 99% level with a positive sign in relation to the omitted variable of high density residential origin. The distance added is noteworthy. For example, commutes from single family and park origins are shown to be 4.5 km and 3 km longer than high density residential respectively. Urban mixed use origins are significantly correlated with commutes of almost a kilometre shorter than high density residential; this is the only origin cluster seen to be negatively correlated with commute lengths. New high density and commercial streets are not shown to be significantly correlated with trip length in relation to the omitted high density cluster. It is again worth noting that the small size of new high density origins makes this delicate to interpret.

The destination clusters of waterfront, big box, train, institutional and job centres are all correlated with longer work trips. However, the effect on trip length is not as strong as the origin clusters. For example, train, institutional and job-centre destinations are shown to increase trip length by only roughly 1.5 km. This would seem to suggest that the origin of a work trip plays a more important role in determining trip length. Perhaps this points to the importance of understanding residential choice in discussions of commuting length.

It is also worth noting that some unexpected outcomes were found for both suburban and high density residential mixed use areas. New high density destinations are not shown to be significant relative to high density destinations in predicting commute length. In addition, while single-family origins generate much longer trips, suburban destinations are not shown to be correlated with longer commutes.

These findings are also similar to Barbonne's work cited above. In fact, they are all the more interesting as this study looks not just at one neighbourhood in a geographical sense but on a particular type of neighbourhood that is scattered across the region. This point should be underlined, while urban mixed use and high density residential clusters seem to be "exporting" shorter and "better" *i.e*. transit and active trips, these types of areas are "importing" longer car trips. Most noteworthy is the fact that the average length of car trips *to* high density areas is actually longer than the average car trip *to* a suburban location. Also noteworthy is the fact the average distance of single-family to suburbs is well below the average distance of all home-to-work car trips of 14 km. Please refer to Table 10.

The significance and magnitude of the geographic dummies are also important. Trips that stay in one sub-region, that is do not cross a bridge, are significantly shorter. While this is somewhat intuitive, it is important to point out the each sub-region is quite large; the island is roughly 51 network km from tip to tip. In addition the North and South Shore regions are each larger than the island of Montreal. The coefficients also suggest that both living and working in Laval has the strongest negative effect on trip lengths.

Variable	Base Model		Expanded Model	
(Constant)	**3336.227**	**4.710**	**15651.862**	**25.785**
Number of Vehicles	**1471.863**	**18.223**	**529.580**	**7.915**
People	**816.341**	**10.706**	**306.551**	**4.968**
Male Dummy	**2486.476**	**19.429**	**1392.727**	**13.352**
Age	**400.226**	**11.842**	**144.862**	**5.305**
Age squared	**-5.053**	**-12.704**	**-2.159**	**-6.720**
Low Income Dummy	**-2737.465**	**-7.649**	**-1057.707**	**-3.665**
High Income Dummy	**893.480**	**4.740**	**547.317**	**3.580**
AM Peak Dummy	**-839.035**	**-5.872**	**-469.246**	**-4.074**
PM Peak Dummy	**-1811.845**	**-5.087**	**-1198.833**	**-4.180**
Number of trips (individual)	**-1158.329**	**-12.189**	**-575.078**	**-7.500**
Total trips (household)	**-330.811**	**-14.329**	**-187.337**	**-10.059**
Full Time Dummy	**2072.478**	**9.489**	**996.217**	**5.645**
Live and Work Laval			**-15774.112**	**-61.668**
Live and Work Island			**-10891.321**	**-81.865**
Live and Work South Shore			**-13417.825**	**-79.914**
Live and Work North Shore			**-14238.489**	**-74.608**
Origin Park			**2909.990**	**4.251**
Origin Big Box			**1821.473**	**4.568**
Origin Train			**2310.664**	**5.768**
Origin New High Density			3591.529	.694
Origin Single Family			**4528.018**	**33.357**
Origin Highway			**1510.375**	**5.998**
Origin Commercial Streets			-222.802	-.641
Origin Waterfront			**5707.378**	**14.593**
Origin Urban Mixed Use			**-889.848**	**-3.752**
Destination Park			-316.176	-.283
Destination Waterfront			**1199.416**	**2.637**
Destination New High Density			618.548	2.064
Destination Golf			691.567	.697
Destination Suburb			187.242	.943
Destination Big Box			556.796	2.257*
Destination Train			**1258.630**	**5.743**
Destination Institutional			**1378.579**	**6.199**
Destination Job Centre			**1670.236**	**8.833**
Dependent Variable Length	R Square .061		R Square .392	

* Significant at 95% level, variables in bold are significant at the 99% level.

Table 13 Linear Regression for length of car work trips

One of the most striking findings of this analysis is shown in Table 14. Average distance travelled for commuters who cross one of the regional bridges are over twice as long as those who stay in a sub-region. Commuters who both live and work in Laval travel the shortest average distances. This could have profound influence on several regional policy possibilities such as bridge tolls and increasing employment opportunities in the suburbs. Limiting bridge traffic would have the effect of both drastically reducing VMT and congestion.

Geography	Count	Average Distance
Live Work Island	12148	9941.33
Live Work Laval	1420	7081.49
Live Work South Shore	4169	9576.31
Live Work North Shore	3014	9355.26
Cross Bridge	11249	23608.28

Table 14: Trip Distance by Region

STUDY LIMITATIONS

As with any study, this research was faced with several issues, these will be discussed below. While the technique of factor and cluster has been shown to be an effective way of reducing large datasets and revealing hidden factors, it also has some inherent weaknesses. As mentioned briefly above, these include researching subjectivity, particularly in the naming of both the factors and clusters, and certain unwieldiness in its adaptability. For example, unlike a simple regression model in which a variable can simply be inserted or deleted, the nature of the factor and cluster analysis requires hours of computing time and analysis if one is to add or remove data and/or variables. In this research, variables that might have improved the overall performance of the model were, in fact, not included as they were located well after the analysis was completed.

In addition, this technique is a powerful way to reduce very large datasets to something both meaningful and practical. It proved quite effective at doing just that in this study. However, it should be noted that it is not necessarily the best, and certainly not the only way to approach neighbourhood and urban form analysis. It could be argued that a smaller sample of neighbourhoods with a variety of quantitative and qualitative approaches could give more accurate – though it would certainly be much smaller in scope – results than this research. However, the trade-off between being able to analyse such a large amount of individual trips and areas and looking at a small fraction of the information, made this approach desirable. A case-study approach would have also allowed for the inclusion of other important information, traveller attitudes, and employer policies in regards to parking, whether transit passes are included in a benefit package, past travel patterns and residential location information. This, needless to say, was not included in the present analysis. Having said that, as the point of this research was on urban form, many of the above criticisms are a bit extreme. Other data that could be useful are accurate travel time differentials between car and transit trips as well as transit costs by region.

The last point is data accessibility. Although this study was able to make use of an incredibly wide range of data sources of very high quality and accuracy, some important data were missing and/or incomplete. Two important examples are the fact that both bus stop locations and cycle lane data were only available for the island of Montréal. Cycle lane information was dropped entirely from the analysis due to consistency while number of individual bus lines and a dummy variable capturing whether a bus passes through a particular cell were used instead. Other data that could have proved useful include parking availability and rates, traffic counts and accurate transit times for all trips. In addition metro and train locations were given simply by a point in a GIS shapefile, no information on the physical location of entryways, let alone any kind of information on stairs, escalators or elevators was available. As ride-sharing and increasing vehicle occupancy are effective ways in which to lower overall VMT, data on vehicle occupancy would also be of interest to researchers. I did not have access to this data from the Montréal O-D survey. In addition, while I feel confident that exploring weekday home-to-work trips only is a valid approach, it must be noted that other trip purposes and week-end travel could make these types of studies even more robust.

Conclusions

This paper first develops a useful and easy way in which to visualize and characterize urban form, land demographic, and accessibility measures for thousands of home and work locations throughout the region of Montréal using factor and cluster analysis. The factor and cluster analysis is interesting in its own right and even more so for its help in understanding regional travel behaviour. By revealing deeper patterns of urban form, the analysis shows that how certain neighbourhood typologies are spatially spread out throughout the region.

Using detailed individual, household and geographical information, individual trips are analysed in the context of the land use measures at the point of origin and destination. This allows for the development of a linear regression to predict length of travel by automobile for home-to-work trips. The characteristics at the point of origin coupled with demographic information go a long way in understanding trip length. Furthermore, while most of the findings here are supported by previous research, many noteworthy findings were also extracted. In addition, many intuitive but nonetheless important findings are also presented.

The paper also shows the importance of demographics and households and as well as – the unobserved preferences of travellers – the cluster information alone, while quite useful does not allow the researcher to make the type of conclusions and analysis that are possible with the full data set. However, it is interesting that this research confirms many claims made by advocates of neighbourhood design effects on travel. Here we see that people who live in denser neighbourhoods, regardless of geography have different travel behaviour than those who live in predominantly single-family areas regardless if they are on the island or in far-flung suburban areas. What this research is unable to do, is make claims about the causality of any of these findings. As many have discovered before, this is the most difficult aspect this type of research. While it is hoped that this paper can add to the understanding about the complex relationship between travel and neighbourhood design, without the understanding of individual travel preferences and location choice decisions, it becomes near-impossible to make any claims other than to describe and attempt to make sense of the data.

However, with a very large number of observations, a set-up that takes into account micro-scale (cell), small-scale (neighbouring cells) as well as census-tract level demographic data, dummy variables to account for geographic location in addition to the disaggregate data available for the individual as well as the household, it seems clear that this research is able to make some interesting insights into the debate over urban form and travel behaviour on a regional scale. While a basic geographic analysis seems to confirm assumptions about “downtown” versus “surburban” travel behaviour, the cluster analysis reveals more subtlety. Furthermore, it seems that certain issues of behaviour can be generalized based on neighbourhood types. In addition, this study opens up many avenues for future study.

Policy Implications

This section presents policy implications of this research and points towards further issues to explore. Commutes crossing bridges to the island of Montreal are the longest trips in the region. This has several implications: These trips therefore contribute a higher amount of pollution based on their VMT, but, because they are forced to go over one of fourteen bridges, are also responsible for increased congestion. These reasons would support the – contentious – idea that bridge tolls should be implemented, that transit should increase its regional offer and that higher concentrations of employment opportunities should be encouraged in suburban locations. However as Badoe and Miller (2000) point out, efforts to increase transit use are often not as effective as desired. They cite Webber (1976) who found that most users of BART after one year of operation had previously taken the bus. The idea of bridge tolls in Montréal has also been met with strong opposition. Yet it seems to have potential to be one of the most effective ways to decrease VMT in the Montreal region.

Suburb-to-Suburb commuting is both quite prevalent and predominantly car dominated, however it is far from the longest commute in the region. However, in contrast to the single-family-to-suburban travel, most car trips that originate in single family areas or go to job centres are much longer than other trips. This also seems to confirm the usefulness of having a better mix of jobs and residences in the suburbs. Both of these findings point towards the importance of a better mix of employment and residences in the suburbs.

Many assumptions are upheld in this analysis, residents of dense mixed-use travel shorter distances by “better” modes of transportation. However, these areas also bring in travelers from long distances, including many by car. Of special interest is the dissonance between trips in and out of certain types of areas. In particular, the fact that while commutes from high density residential are shown to be shorter and less car-centric, many of the commutes into high density areas are, in fact, longer than the regional average. Of course, it must be noted that, due to the set-up of this research, the actual geographic location of these clusters does not come into play. That is, I cannot claim that a particular cell generates longer trips than it attracts, for example, simply that home and work clusters identified as high density show remarkably different in and out behaviour. Also apparent from the transit use figures is the fact that transit needs to be easily accessible at both ends of a trip to be a practical possibility.

"Suburban type development" is more spread out spatially than often thought. The geographical spatial distribution of clusters is also noteworthy in its own right and gives a nuanced picture of regional home and work locations. In addition, the fact that "suburban" travel behaviour is relatively consistent regardless of geography is noteworthy. In fact, perhaps the most intriguing issue brought up here is the fact that the type of neighbourhood cluster does a relatively decent job of estimating travel behaviour when geography is controlled for.

Reducing VMT will require investment in transit infrastructure, education and policies to encourage growth in already established corridors and TODs. As the demographic analysis showed, it is predominantly wealthy males over the age of thirty-five who are contributing the largest share of VMT in the region. While I cannot claim to offer a solution, it seems that in addition to the many options already suggested to combat VMT, that some sort of targeted marketing or educational program targeting that demographic might have some success. As Kitamura *et al*. proposed in 1997, a thorough understanding of how travel *attitudes* are formed, how they relate to residential and workplace location decisions and vehicle acquisition decisions and lastly, how they can be altered by land use policy is absolutely vital in any discussion of travel behaviour.

A strength of this research is the combination of both a cluster- and geographical- based approach, while controlling for individual and household variables. It is noteworthy that certain cluster-to-cluster patterns are relatively consistent regardless of geography and that, perhaps, certain key issues of regional patterns are best understood by geographic criteria; the length of intra-Laval trips and "crossing bridge" are the clearest examples.

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Appendix I Factor Loadings and Cluster Centroid Values

Residential Location Factor Grid

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
	Population Density	**Household Structure**	**Income Housing Value**	**Commercial Activity**	**Retail**	**Services Nearby**
Population	**0.96**	-0.03	0.01	0.01	0.03	0.04
N Population	**0.93**	-0.03	0.02	0.03	0.09	0.12
Pre-46 Dwellings	**0.67**	-0.17	0.12	-0.03	0.11	0.41
N pre-46 dwellings	**0.63**	-0.17	0.13	-0.02	0.16	0.47
University	**0.75**	-0.18	0.35	0.00	0.08	0.19
N university	**0.71**	-0.18	0.37	0.02	0.14	0.27
apartments	**0.93**	-0.18	0.00	0.02	0.06	0.11
N apartments	**0.89**	-0.19	-0.01	0.04	0.12	0.19
Trade school grads	**0.89**	0.03	-0.17	0.00	-0.02	-0.08
N trade school grads	**0.86**	0.03	-0.19	0.02	0.04	-0.01
Unemployed	**0.89**	0.00	-0.09	0.04	0.05	0.06
N unemployed	**0.88**	-0.02	-0.10	0.06	0.10	0.14
High School Grads	**0.90**	0.01	-0.14	0.01	-0.02	-0.11
N High School Grads	**0.88**	0.01	-0.16	0.04	0.03	-0.05
Number of rented units	**0.92**	-0.15	-0.02	0.02	0.06	0.12
N rented units	**0.89**	-0.17	-0.02	0.04	0.12	0.20
Workers	**0.95**	-0.06	0.07	-0.01	0.04	0.09
N workers	**0.91**	-0.06	0.07	0.02	0.11	0.18
Dwellings	**0.95**	-0.12	0.03	0.01	0.05	0.09
N dwellings	**0.92**	-0.13	0.03	0.03	0.11	0.17
owned	**0.68**	0.03	0.21	-0.05	-0.03	-0.09
distance	**-0.55**	0.20	-0.29	-0.09	-0.08	-0.01
Average number of people	-0.05	**0.89**	0.18	-0.02	-0.03	-0.07
N Avg number of people	0.09	**0.76**	0.24	-0.07	-0.04	-0.01
Number of rooms	-0.37	**0.75**	0.38	-0.04	-0.07	-0.06
N number of rooms	-0.24	**0.69**	0.41	-0.07	-0.07	-0.02
Number of bedrooms	-0.42	**0.77**	0.27	-0.03	-0.09	-0.11
N Number of bedrooms	-0.30	**0.72**	0.32	-0.06	-0.09	-0.07
Average number of children	-0.10	**0.92**	0.05	-0.01	-0.05	-0.09
N Children	0.00	**0.84**	0.12	-0.05	-0.05	-0.05
Median Household Income	-0.35	0.42	**0.72**	-0.03	-0.05	-0.05
N Income	-0.26	0.42	**0.74**	-0.05	-0.05	-0.02
Average Rent	-0.04	0.34	**0.64**	-0.02	0.01	0.00
N Rent	0.05	0.28	**0.61**	-0.05	0.02	0.07
Dwelling Value	0.18	0.13	**0.84**	0.06	0.03	-0.02
N Value	0.24	0.13	**0.85**	0.03	0.03	0.00
Commercial	0.04	-0.06	-0.01	**0.77**	0.27	0.13
N commercial	0.13	-0.08	0.00	**0.89**	0.10	0.19
Commercial Attached	-0.02	-0.02	-0.01	**0.90**	-0.01	-0.03
N commercial attached	0.00	-0.02	0.00	**0.92**	-0.05	-0.02
Variance Explained	29.3	12.3	5.8	4.5	3.8	3.3
Total	29.3	41.7	47.5	52.0	55.8	59.1

Residential Matrix (Con't)

	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
	Parks Golf	**Industrial**	**Commuter Train**	**Newer**	**Gov Insti**	**No Water**	**Train Tracks**	**Highway**	**Owned**
Retail	-0.03	-0.06	0.02	0.03	0.05	0.01	0.06	0.03	0.07
Manufacturing Jobs	-0.01	0.19	0.05	0.00	-0.01	0.03	0.00	0.01	-0.04
Retail	0.00	0.10	0.01	0.00	0.01	0.00	-0.04	0.04	-0.04
Restaurants	-0.01	-0.04	-0.01	0.02	0.00	-0.01	0.00	0.00	0.03
N retail	0.01	0.32	0.09	-0.06	0.03	0.02	-0.12	0.12	-0.01
N retail 2	-0.04	-0.01	0.05	0.06	0.07	0.03	0.07	0.02	0.04
N manufacturing Jobs	-0.02	0.27	0.06	0.02	0.03	0.05	-0.01	0.05	-0.06
N restaurants	0.00	0.04	0.06	0.00	0.00	0.00	-0.08	0.03	0.03
Parks	**0.66**	-0.04	-0.03	-0.09	0.07	-0.03	0.02	-0.04	0.18
N park	**0.74**	-0.05	0.01	-0.09	0.03	0.06	-0.04	-0.05	0.01
Gold	**0.79**	0.01	0.01	0.06	-0.06	0.01	0.00	0.02	-0.08
N golf	**0.81**	0.00	0.01	0.06	-0.08	0.02	-0.01	0.01	-0.11
industry	-0.05	**0.80**	-0.04	-0.01	0.00	0.01	0.13	-0.03	0.12
N industry	-0.07	**0.80**	0.06	0.01	-0.03	0.10	0.07	0.01	-0.13
Commuter Train Acces	0.00	0.01	**0.92**	-0.01	0.05	-0.03	0.16	0.03	0.01
N commuter Train	0.01	0.02	**0.92**	-0.02	0.05	-0.03	0.19	0.04	0.00
New Construction	-0.03	-0.02	0.01	**0.94**	-0.06	0.04	-0.05	-0.01	-0.09
N New Construction	-0.01	0.01	-0.04	**0.95**	0.01	0.02	0.00	-0.01	0.11
Government Institutional	-0.02	-0.09	0.02	-0.01	**0.86**	0.05	-0.03	-0.01	0.10
N Government Instit.	-0.05	0.09	0.09	-0.04	**0.75**	0.13	-0.06	-0.01	-0.14
Water	-0.03	-0.03	0.03	-0.01	-0.07	**-0.86**	-0.04	0.00	0.02
N Water	-0.04	-0.07	0.03	-0.04	-0.09	**-0.84**	-0.05	0.01	-0.05
Train Length	-0.01	0.06	0.09	-0.01	-0.04	0.04	**0.80**	0.03	0.01
N Train Length	-0.02	0.08	0.29	-0.03	-0.03	0.05	**0.76**	0.06	-0.04
Highway Length	-0.02	-0.01	-0.01	-0.01	0.01	-0.03	0.05	**0.86**	0.01
N Highway Length	-0.04	0.01	0.08	-0.01	-0.02	0.02	0.04	**0.85**	-0.02
N owned	-0.07	-0.01	0.00	0.14	-0.11	0.14	-0.10	-0.06	**0.44**
Variance Explained	3.0	2.9	2.7	2.3	2.2	2.1	1.9	1.9	1.8
Total	**62.2**	**65.1**	**67.8**	**70.0**	**72.2**	**74.3**	**76.2**	**78.1**	**79.9**

Work Location Factor Matrix

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
	High Density Residential	**Single Family**	**Big Box**	**Highway**	**Local Roads**	**Park Golf**
Total Population	**0.927**	0.121	-0.035	-0.023	0.108	-0.008
N Total Population	**0.918**	0.140	0.003	0.007	0.071	-0.041
Owned	**0.645**	0.331	-0.078	-0.038	0.170	-0.027
N Owned	**0.647**	0.377	-0.028	-0.005	0.129	-0.059
Construction pre-46	**0.828**	-0.008	-0.005	-0.020	0.052	0.018
N Construction pre-46	**0.798**	0.016	0.005	-0.005	0.042	-0.006
University grad	**0.860**	0.099	-0.007	-0.016	0.026	0.028
N University grads	**0.853**	0.123	0.018	0.013	0.004	0.001
Unemployed	**0.895**	0.016	-0.012	-0.018	0.064	-0.001
Workers	**0.930**	0.132	-0.038	-0.022	0.097	-0.003
N workers	**0.920**	0.152	-0.001	0.010	0.064	-0.037
rented	**0.948**	-0.011	-0.008	-0.012	0.054	0.014
N rented	**0.943**	-0.003	0.016	0.016	0.032	-0.017
Total Dwellings	**0.949**	0.065	-0.023	-0.018	0.087	0.005
N Total Dwellings	**0.944**	0.082	0.009	0.014	0.059	-0.028
Apartments	**0.959**	-0.012	-0.008	-0.010	0.069	0.014
N Apartments	**0.946**	-0.004	0.017	0.018	0.046	-0.018
n_u_18	**0.773**	0.222	-0.017	-0.014	0.068	-0.062
Industry	-0.196	**-0.528**	-0.179	-0.062	-0.051	-0.137
N Industry	-0.172	**-0.581**	-0.181	-0.028	-0.025	-0.124
N Residential	0.282	**0.642**	-0.067	-0.033	0.110	-0.093
Dwelling Value	0.279	**0.793**	-0.020	-0.007	0.092	0.035
N Dwelling Value	0.341	**0.692**	0.004	-0.018	0.084	0.006
N Rent	0.213	**0.782**	0.020	0.000	0.079	-0.045
N Number of Bedrooms	-0.031	**0.843**	0.001	-0.026	0.039	-0.061
N Rooms	0.045	**0.853**	-0.003	-0.024	0.048	-0.051
Number of Children	0.092	**0.882**	-0.042	-0.013	0.046	-0.032
rented	0.156	**0.897**	-0.014	0.021	0.092	0.008
Number of People	0.158	**0.916**	-0.038	0.010	0.079	-0.022
Median Household Income	-0.053	**0.919**	-0.041	-0.010	0.065	0.025
Number of bedrooms	-0.069	**0.941**	-0.031	-0.008	0.046	-0.018
Number of rooms	-0.002	**0.952**	-0.035	-0.005	0.055	-0.008
Commercial	0.032	-0.025	**0.859**	0.007	-0.044	-0.028
N Commercial	0.037	-0.042	**0.949**	0.045	-0.022	-0.013
N_commtot	-0.071	-0.051	**0.930**	0.032	-0.038	-0.011
Bus Service	0.125	0.078	0.065	**0.519**	0.023	-0.043
N Bus Service	0.258	0.011	0.158	**0.527**	0.022	-0.085
Highway in Grid	-0.092	-0.018	-0.010	**0.788**	-0.145	-0.002
Highway Length	-0.105	-0.045	-0.003	**0.841**	-0.042	0.005
N Highway Length	-0.108	-0.102	0.037	**0.745**	-0.056	-0.016
Road Length	0.162	0.126	-0.016	0.613	**0.564**	-0.019
Local Road length	0.265	0.199	-0.087	-0.188	**0.806**	-0.048
Local Roads	0.241	0.212	-0.035	-0.066	**0.902**	-0.031
Number of Intersections	0.163	0.162	-0.005	0.005	**0.915**	0.002
Parks	-0.040	-0.055	-0.043	-0.059	-0.008	**0.629**
N Parks	0.015	-0.033	-0.051	-0.069	0.055	**0.723**
Golf	-0.038	-0.027	0.000	-0.007	-0.054	**0.875**
N golf	-0.053	-0.026	0.001	-0.004	-0.045	**0.876**
Variance Explained	25.748	14.511	5.324	4.469	4.298	3.831
Total	**25.748**	**40.259**	**45.583**	**50.052**	**54.350**	**58.181**

Work Location Matrix (Con't)

	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12	Factor 13	Factor 14	Factor 15
	Train	**SDH**	**Open**	**Jobs**	**Retail**	**Instit.**	**Services**	**Water**	**Newer**
N Train Length	**0.721**	-0.090	0.042	-0.018	0.043	-0.048	-0.045	-0.029	-0.066
Access Commuter Train	**0.862**	0.089	-0.027	0.031	0.027	0.076	0.129	0.015	0.030
N Access Commuter Train	**0.881**	0.075	-0.019	0.026	0.036	0.078	0.124	0.009	0.019
Single-detached homes	-0.072	**0.641**	0.196	-0.148	-0.139	-0.164	-0.107	-0.049	0.017
N Single Detached homes	-0.063	**0.534**	0.260	-0.201	-0.225	-0.096	-0.118	-0.093	0.001
Residential	-0.036	**0.609**	0.147	-0.031	-0.060	-0.185	-0.073	-0.001	0.112
Open	-0.025	-0.141	**-0.783**	-0.002	-0.082	-0.057	-0.051	-0.029	-0.036
N Open	-0.036	-0.070	**-0.837**	0.000	-0.060	-0.104	-0.045	-0.045	-0.008
Manufacturing Jobs	-0.011	-0.054	-0.017	**0.701**	0.292	-0.102	0.107	-0.071	0.011
Total Jobs	0.032	-0.106	-0.020	**0.765**	0.326	-0.023	0.075	-0.046	0.010
Management Jobs	-0.023	-0.009	0.029	**0.800**	-0.144	0.139	-0.003	-0.008	-0.036
ave_profes	0.028	-0.085	0.094	0.174	**0.530**	-0.060	-0.028	-0.045	0.034
ave_retail	0.095	-0.061	0.055	0.124	**0.573**	0.129	-0.046	-0.031	0.060
Govt. Institutional	-0.013	-0.085	0.074	-0.009	-0.087	**0.907**	-0.069	-0.038	-0.015
N Govt. Institutional	0.030	-0.047	0.079	0.070	0.144	**0.835**	0.000	-0.026	-0.066
Manufacturing Jobs	0.041	-0.136	0.064	0.111	0.168	-0.111	**0.632**	-0.059	-0.049
Restaurants	0.050	0.008	-0.001	0.025	-0.118	0.041	**0.739**	0.030	0.073
Retail	-0.010	0.001	0.035	0.004	-0.015	-0.015	**0.804**	-0.021	-0.003
Water	-0.010	-0.042	0.024	-0.039	-0.028	-0.025	-0.016	**0.881**	-0.002
N Water	-0.029	0.010	0.013	-0.047	-0.065	-0.030	-0.027	**0.902**	-0.019
New Construction	-0.054	0.124	-0.021	0.010	0.086	-0.063	0.006	0.013	**0.870**
N New Construction	-0.057	-0.041	0.059	-0.035	-0.010	-0.023	0.027	-0.040	**0.889**
	3.300	3.029	2.825	2.451	2.361	2.250	2.058	1.775	1.635
	61.481	**64.510**	**67.335**	**69.785**	**72.146**	**74.396**	**76.454**	**78.230**	**79.865**

Residential Locations Cluster Centroid Values

	Park	Big Box	Train	High Density Res	New High Density	Single Family	Highway	Retail Jobs	Water Front	Urban Mixed
Population Density	-0.64	-0.28	0.15	0.55	8.21	-0.43	-0.14	0.50	-0.60	2.15
Household Structure	-0.21	-0.10	-0.05	-0.47	-2.95	0.36	-0.27	-0.31	-0.82	-0.54
Income/Housing Value	-0.37	-0.08	-0.03	0.18	2.70	-0.08	-0.06	0.03	-0.27	0.23
Commercial Activity	-0.12	5.98	-0.05	-0.09	-0.02	-0.15	-0.11	0.29	-0.19	-0.02
Retail	0.14	-0.36	-0.26	-0.20	-1.51	-0.08	-0.04	5.19	-0.16	-0.31
Services Nearby	0.33	-0.21	-0.44	-0.45	-4.84	0.00	0.06	0.31	-0.11	2.42
Parks/Golf	8.99	-0.07	-0.13	0.09	-0.71	-0.12	-0.09	-0.06	-0.26	-0.04
Industrial	0.00	0.06	0.51	0.59	-1.34	-0.27	0.06	0.17	-0.28	-0.38
Commuter Train	0.09	-0.08	1.19	0.12	8.39	-0.08	0.05	0.15	0.17	-0.44
Newer	0.62	-0.08	-0.10	-0.21	3.49	0.07	-0.03	0.09	-0.18	0.36
Gov. Institutional	-0.79	-0.08	-0.30	0.47	-8.09	-0.20	-0.02	0.08	-0.45	0.11
No Water	0.22	0.08	0.29	0.11	4.10	0.15	0.15	0.03	-5.20	-0.09
Train Tracks	-0.08	-0.11	5.16	-0.28	-7.22	-0.04	-0.12	-0.05	-0.26	0.26
Highway	0.08	-0.02	0.02	-0.21	-0.76	-0.19	3.24	-0.08	-0.06	-0.24
Owned	-0.97	-0.11	0.04	0.23	-7.67	-0.05	-0.05	0.17	-0.11	-0.46

Work Location Cluster Centroid Values

Factor	Park	Water Front	New High Density	Office Park	Suburb	Big Box	High Density	Train	Instit.	Job Centre
High Density	-0.50	-0.41	0.99	-0.51	-0.20	-0.43	2.19	-0.17	-0.17	-0.48
Single Family	-0.10	-0.05	0.01	-0.35	0.48	-0.16	-0.04	0.06	-0.11	-0.60
Big Box	-0.18	-0.19	0.01	0.06	-0.16	3.97	0.02	-0.04	-0.15	-0.34
Bus service/highway	-0.19	0.10	-0.05	-0.13	-0.02	0.10	-0.03	0.14	-0.10	0.01
Local Roads	-0.02	-0.46	0.44	-0.99	0.17	-0.21	0.09	0.20	-0.30	-0.24
Parks golf	6.07	-0.10	0.01	13.76	0.01	-0.09	0.00	-0.04	-0.07	-0.22
Train Infrastructure	-0.15	-0.10	-0.26	-0.32	-0.28	-0.21	-0.21	2.95	-0.18	-0.28
Single Detached	0.53	-0.19	-0.45	1.07	0.52	-0.15	-0.11	0.17	-0.24	-0.58
Open Park	-0.45	0.13	0.04	-0.44	0.40	-0.01	-0.07	-0.03	0.18	-0.57
Jobs	-0.43	-0.24	-0.09	-1.65	-0.05	0.02	-0.05	0.10	0.10	0.09
Retail	1.10	-0.25	0.24	2.40	-0.35	0.06	0.00	0.10	-0.14	0.42
Institutional	0.21	-0.22	-0.03	0.09	-0.22	-0.20	-0.05	0.04	2.90	-0.40
Services	0.29	-0.11	0.16	0.77	-0.22	-0.06	0.28	0.33	-0.19	0.13
Water	-0.19	5.63	0.02	-0.81	-0.11	-0.09	-0.02	-0.05	-0.09	-0.23
Newer	0.09	-0.08	3.60	-0.22	-0.06	-0.14	-0.54	0.06	-0.12	-0.19

Appendix II Additional Transit Analysis

Transit Modal Split

Of the 8489 transit trips looked at, 2200 are by Metro, 397 by Train and 5724 are by Bus, including STM as well as the other five regional bus providers. High Density Residential generates by far the most transit trips, followed by Single Family and Urban Mixed areas. Interestingly, while Single-Family areas supply more than 50% of the Train commutes, they are responsible for only 26% of the bus trips.

By far the largest destination cluster for transit trips – for all modes – is the commuter train areas. These areas also draw people in from the farthest average distance, almost twelve kilometres. This confirms prior research and basic economic theory, being faster and more comfortable, a twelve kilometre train commute would be significantly more attractive than a twelve kilometre bus trip.

The largest single cluster pair is High Density Residential to Train, these trips account for 12% of all regional transit trips. Other important cluster pairs are Single Family to Train, Urban Mixed Use to Train, Urban Mixed Use to High Density Residential and High Density Residential to High Density.

Different transit modes are responsible for drastically different travel distances, as seen in Table 10.

	Count	Length(m)
STM	4027	9066
Metro	2200	7835
RTL	944	11916
STL	411	14445
CIT	296	23072
TRAIN	397	21196
Other Bus	46	15337
	8489	10365

Table i: Transit Modal Split and Distance

There is a wide variance in the distance of transit trips by cluster of Origin. Urban Mixed Use areas have a shorter transit commute by less than half in relation to Waterfront, Park and Single Family areas. High density residential, commercial streets and Train areas also exhibit significantly shorter transit distances. It is especially interesting to contrast the difference between the origins of car and transit trips. For example, while Urban Mixed Use areas and High Density Residential are only responsible for 38.7% of all trips, they generate 62.8% of transit trips. There is a notable contrast between Single-Family areas which generate 47.7% of all trips yet only 20.7% of transit trips. There is a remarkable difference in the distance in and out of the clusters. While the distances into the destinations clusters are somewhat, surprisingly, similar, Institutional, Train and Job Centre attract the longest trips. Also the difference between transit trips coming from the Train Residential cluster and the Train Work location cluster confirms what Tsai (2008) found in research on the usage of the Taipei transit system.

Origin	Metro	Train	Bus
Park	0	7	23
Big Box	14	5	124
Train	44	54	116
High Density Res	899	96	2613
New High Density	0		1
Single Family	23	193	1499
Highway	118	22	285
Retail/Jobs	239	3	278
Water Front	3	13	33
Urban Mixed-Use	860	4	752
Total	2200	397	5724

Destination	Metro	Train	Bus
Park			9
Water Front	8	2	38
New High Density	278	29	441
Office Park			6
Suburban	164	19	683
Big Box	81	10	435
High Density Res	399	41	1045
Train	766	252	1653
Institutional	232	26	583
Job Centre	272	18	831
	2200	397	5724

Table ii: Transit Origins and Destinations

The single longest transit distance is Waterfront areas to High Density Residential. See Appendix for additional figures with additional breakdown into mode. It is also interesting to note that areas identified as Train work locations actually have a much higher percentage of bus trips ending there. This might reveal more about the nature of the Montréal transit system than anything else, namely that most Commuter Train stations downtown are also served by the Metro and all of them are connected to bus service.

A last finding concerning income, vehicle and ownership; while it is intuitive that wealthier households would own more vehicles, and that most transit users would not be car owners, what is surprising is that vehicle ownership appears to have a positive correlation with transit trip length. This might be related to perception of distance for car owners or simply be a reflection of the difference in spatial distribution of low versus high paying employment. Table 12 shows the number of vehicles owned and average distance travelled. A full 85% of transit users come from a household with one or less vehicles. Somewhat promising for transit use, however, is the fact that 12% of households using transit for work trips own two vehicles. While it is well beyond the scope of the current paper to explore this further, it is obvious that this dataset could be examined further with regards to income, gender, dual-earner household, car ownership and transit use.

Number of Vehicles	Average Distance	Count
Zero	8112.80165	3275
One	11197.76973	3915
Two	13375.30825	1095
Three	13923.17027	167
Four or more	16342.20023	37

Table iii: Transit use and car availability

APPENDIX III ADDITIONAL FIGURES

Mode	Frequency	Percent	
Driver	34540	69.6	Car Total 77.07%
Passenger	3727	7.5	
STM	3996	8.0	Transit Total 17.05%
Metro	2167	4.4	
RTL	931	1.9	
STL	408	0.8	
CIT	324	0.7	
Train	397	0.8	
Other Bus	57	0.1	
Taxi	187	0.4	
Cycle	612	1.2	Active Total 5.77%
Walk	2255	4.5	

Table iv Additional breakdown by mode of work trips

	Car	Transit	Cycle	Walk
Male	57.0	44.0	66.1	42.3
Female	43.0	56.0	33.9	57.7

Table v Mode and Gender